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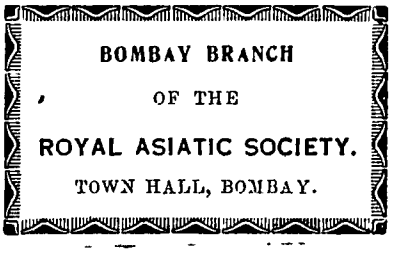

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1 Scientific Research in India
— Prof A.V. Hill - Simla.
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SCIENTIFIC RESEARCH IN INDIA

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BY

PROFESSOR A. V. HILL, M. P., SC. D., F. R. S.
(Secretary and Research Professor of the Royal Society)

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PRINTED BY THE MANAGER, GOVERNMENT OF INDIA PRESS, SIMLA
1945

Price : Annas 8 or 9d.

SCIENTIFIC RESEARCH IN INDIA

by Professor A. V. Hill, M.P., Sc.D., F.R.S.

PREFACE

The following 'report' on *Scientific Research in India* makes no claim to formality or completeness. As 'Notes and Suggestions' it was written first, informally and confidentially for the Government of India, as the basis for discussion before I left last April. To a large extent it was a log-book of the travels, visits, arguments and observations of the previous four months. A strong desire, however, was expressed that something of the kind should be made more generally available, and I promised to put my 'notes and suggestions' into a form rather more suitable for publication.

Various additions have been made and the material has been rearranged; but it still seems rather like a 'log', dealing chiefly with what one saw and heard. For incompleteness and possible inaccuracies, shortness of time and lack of previous knowledge of India may be an excuse: for frankness or indiscretion my Indian colleagues must share responsibility—through their firm insistence that discretion is not always the better part of valour. For the comments and opinions expressed I alone am answerable: they may often appear critical, but friendly criticism is a necessary step to progress—at least in science—and I do not underrate the achievements of Indian science and technology in the last 30 years. Indeed, I often had to say, when Indian friends seemed glum about it, that scientific advance in India has been greater in those 30 years than in all previous history. It is coming now to the steeper part of a rising curve.

Various proposals and recommendations are made in the following pages: some of them, it seems, are being adopted already; some of them will need careful working out as part of a long-range plan; others may prove impracticable. I have assumed throughout that the scientific method, rightly and confidently used, will provide the framework within which national development will be planned by Indians for India. In their task they can be sure of the co-operation and goodwill of their scientific colleagues elsewhere. No other method can possibly succeed.

I am deeply grateful to the Government of India for its invitation and for unlimited facilities throughout my visit. To the Department of Education, Health and Lands I would offer special thanks for the care and efficiency of their arrangements: but to many other Departments also my thanks are due for their interest and instant help whenever wanted. To innumerable friends and colleagues all over India I would express profound gratitude for their welcome and encouragement, for their guidance and their boundless hospitality. I shall recall my visit not only with lasting interest but with warm affection.

A. V. HILL.

The Royal Society,
London, W.1.,
14th *August* 1944.

SCIENTIFIC RESEARCH IN INDIA

By Professor A. V. Hill, M.P., Sc.D., F.R.S.

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SCIENTIFIC RESEARCH IN INDIA

(1) INTRODUCTION

It is commonly realized that scientific research and the application of scientific knowledge have played a large and essential part in the war effort of all the nations engaged in the present conflict. Between 1939 and 1941 arrangements were made between the United Kingdom, the Dominions and the United States for close co-operation in scientific research and full communication of scientific and technical information in all matters connected with the war. The Dominions and the United States now maintain scientific missions or representatives in London : the United Kingdom has a scientific representative at Ottawa : and a British Central Scientific Office at Washington acts jointly for the United Kingdom and the Dominions for scientific liaison in the United States. In addition, many special missions, scientific, medical and technical, are continually at work in all these countries, in connexion with weapons, equipment and methods of war, and with problems of food, health, transport, supply, communications, pest-control, etc. The arrangements have worked admirably and have greatly increased the speed and efficiency with which scientific knowledge and research have been applied to the war effort.

It was early realized by scientific men in the United Kingdom that India also ought to be in this picture and in 1941 representations were made through the Secretary of State to the Government of India to that effect. Unfortunately the need was not recognized then in India and no action was taken.

It is not expected that all this cooperation in scientific matters will end when the war is over : for it is obvious that science, applied with the same wholehearted collaboration and conviction to the problems of peace, reconstruction and development—for the betterment of the life of the people of the world—could make just as great a contribution as to war. For that reason the Royal Society in October 1941 took the opportunity of the presence in London during the war of scientific representatives of the Dominions to set up a 'British Commonwealth Science Committee', to consider how collaboration in scientific matters between the various countries of the Commonwealth and Empire could be made closer, and how it could aid in tackling common problems of the immediate post-war period and the future. Unfortunately no Indian scientific men were available in London to attend the meetings, but the Secretary of the Education Department at India House attended and Indian aspects of the problem were considered jointly with the others. The report of the Committee was published* in March 1943 and sent to the Governments of the countries concerned. One of its results is that it is now proposed that an Imperial Scientific Conference shall be called as soon as practicable, after the war, to which scientific representatives of the United Kingdom, India, the Dominions and the Colonies will be invited. At this Conference matters of common scientific interest will be discussed ; and an attempt will be made to formulate a common policy for the interchange of information and research workers, and for cooperation in research and the practical application of results. Once a common policy has been decided on it is hoped to approach the scientific organizations in other countries, particularly the United States, with the purpose of obtaining a more general interchange and cooperation for the same ends.

These various activities, and the feeling among British scientific men that their Indian colleagues should be taking part in them, became known to the

*Reprinted in India in 'Scientific Education and Research in Relation to National Welfare.'; Government of India Press, New Delhi, 1944, pp. 10-17.

Government of India through two Members of the Viceroy's Executive Council who had been present in London in 1942-43 : and in the summer of 1943 the Royal Society was invited by the Secretary of State for India, at the request of the Viceroy, to send a representative to India to advise on the organization of scientific research. In a letter to the President of the Royal Society the Secretary of State wrote :—

> '.....The most important matter to be discussed, I understand, is the organisation of scientific and industrial research as part of the Indian post-war reconstruction plan, and its coördination with the corresponding activities here. But advice would also be welcome on current research problems and visits by a distinguished scientist to universities and other research centres would undoubtedly be much appreciated. I have now been requested by the Viceroy to convey an invitation to the Royal Society to depute a distinguished scientist to visit India, and to enquire whether it will be possible for them to spare Professor A. V. Hill for this purpose... Arrangements would be made for him to see as much as possible of India's scientific, technical and research work.
>
> I myself feel that such a visit would be of very great value both generally in regard to relations between this country and India, and specifically as a means of developing contacts with that country in the scientific and academic field.'

The Royal Society agreed to this proposal and to my absence for four months. I arrived in India on 16 November 1943 and left on 5 April 1944.

I took the Secretary of State's letter as indicating that my advice was sought rather by informal discussion, visits, contacts, etc., and by arrangements which might arise from them, than by the formal writing of a full report. The subject itself was so wide that a longer time and a regular staff would have been required for the latter purpose. It seemed better to get into close personal touch with Indian scientific, industrial, medical and official opinion, and to concern oneself mainly with matters of principle rather than detail. The present report is based on certain notes and suggestions which I left with the Government of India in April 1944, but it refers also to a few matters which have turned up since. One of its objects is to suggest ways in which Indian scientific men can take more part in the general plan of cooperation referred to above.

I visited a large number of centres* where work was going on connected with science, medicine and technology : I was welcomed with the utmost cordiality everywhere, and given the freest access to all information. I could have spent much longer at each place, and could profitably have accepted invitations to many others had there been time. I might have felt embarrassed by the number of speeches, lectures and talks that people wanted me to give—but realized that India has been sorely cut off, in recent years, from intellectual contacts with the rest of the world and that one must do what was physically possible. The great goodwill manifested everywhere towards my mission seemed to have obviated any misunderstanding of its purpose, or any hostile comment in the Press—which was always benevolent—on speeches which had often to be hastily prepared and frequently contained quite frank and critical remarks.

It seemed to be assumed everywhere that my purpose was friendly and helpful ; and since I was in India not as an individual but as a representative of the Royal Society and British science, the hope became a conviction that in

*Aligarh, Bangalore, Bombay, Calcutta, Cawnpore, Delhi, Hyderabad, Jamshedpur, Kirkee, Madras, Mysore, Poona.

the scientific, medical and technical fields there is no difficulty at all in the way of full and friendly cooperation between India and the United Kingdom. In particular, I found everywhere the emphatic opinion expressed—with which I *strongly* agree—that one of the most important needs today of Indian science, medicine and technology is of better facilities to send the ablest of their young people abroad, particularly to the United Kingdom, for advanced and post-graduate study, for works experience and for training in research. In these subjects, at any rate, there is no tendency whatever in India towards isolationism : that swindle has been shown up by world events.

(2) THE LACK OF SCIENTIFIC LIAISON

This complete absence of any spirit of isolationism on the part of Indian scientific, technical and medical people, and their frank recognition of the advantages of cooperation, are in striking contrast with the sorry lack of scientific and technical liaison between Britain and India on problems arising from the emergency of the war. As early as 1940 the Dominion governments appointed scientific liaison officers to their High Commissioners' Offices in London, while in 1941 (9 months before Pearl Harbour) the Office for Scientific Research and Development of the U.S.A. set up at the Embassy in London an Office for the exchange of all scientific and technical information, including the most secret. Corresponding to these, the Government of the United Kingdom in 1940 established a British Central Scientific Office (now in effect a British Commonwealth Scientific Office) in Washington for the same purpose, and from 1940 onwards has maintained at Ottawa, to collaborate similarly with the National Research Council of Canada, a succession of eminent British scientists. There have been frequent visits also, throughout the Empire and the United States, of key scientific men for special purposes. The advantages which have resulted from such free interchanges have been beyond all measure, both for war purposes and for co-operative relations after it.

It is no fault of British scientific men that there is still very inadequate scientific or technical representation of India in the United Knigdom, or that there has been the most meagre representation in India recently of current and up-to-date British science. Even at G.H.Q., India, there has been very little expert contact with the mass of scientific work of all kinds connected with the war which has been done in the United Kingdom, the Dominions and the U.S.A. The consequences have been :—

(a) that Indian scientific people have been quite unnecessarily cut off from association with scientific colleagues in Britain, the Dominions and the U.S.A., and from taking part with them—as many of them have wished —in matters connected with the war :

(b) that India has been needlessly isolated from scientific and technical information which would have been freely available to its scientific representatives in London—had there been any :

(c) that the scientific, and technical resources of India have not been utilised, or developed, for war purposes to anything like the same degree as those of the other major countries.

It is no good crying over spilt milk, but there can be no question now of the necessity of starting up as soon as possible the closer scientific connexions which should have been flourishing already for several years. The Scientific Adviser to the M.G.O., India, has recently been in Britain and America, so his knowledge is now up-to-date, and he has at last the necessary personal contacts with those who are working in the same field. The Government of India has decided to appoint, when a man of sufficient knowledge and experience can be found,

a Scientific Adviser to the Commander-in-Chief. Various scientific missions or parties have recently visited or will shortly be visiting India. A group of Indian scientific men, delayed from May owing to war conditions, will be visiting the United Kingdom in October. I have ascertained that Indian scientific representatives would be very welcome at the British Central Scientific Office in Washington. An offer has been made to the Secretary of State for India, by the President of the Royal Society, that the Society would be glad to nominate a small committee of its Fellows to advise and help the members of an eventual Indian Scientific Office, to be established in London. The Secretaries of the Department of Scientific and Industrial Research and the Medical and Agricultural Research Councils have expressed to me their anxiety to have familiar contact with research in India in their respective fields. Such arrangements, once established, probably would not end there, but would grow outwards into collaboration in general in the fields of education, learning and research, as well as of technology and industry.

(3) RESEARCH TRAINING OF YOUNG INDIANS IN THE UNITED KINGDOM.

India has been largely cut off intellectually for nearly 5 years from the rest of the world. Many of the most prominent Indians in the fields of science, medicine and technology were trained in other countries, particularly in the United Kingdom : some were undergraduate students abroad : others went as advanced students, either to get a higher degree or qualification, or to work with some master of their subject ; or else to get workshop, factory or clinical experience. The universities, medical colleges, research institutions and industrial equipment of India have not yet reached such a level of excellence that this period abroad can be dispensed with, for those who are to be the leaders in their subjects : indeed, in scientific matters no country can be self-contained, and the very great scientific, medical and technical progress of the United States in the present century, has been largely due to the modest readiness of their people to learn from others, and to the excellent provision made for large numbers of them to pursue advanced studies, or to gain experience, abroad.

One of the most urgent needs, therefore, of Indian science, medicine, technology and industry is for young teachers, research workers and members of technical staffs to be provided once more, as soon as conditions allow, with facilities for advanced study abroad ; if possible on an enlarged scale, in order (a) to make up for recent restrictions and (b) to meet the greater needs of the future. The recent training of ' Bevin boys ' in mechanical workshops in the United Kingdom has been a successful and popular experiment, and could be widely extended to cover other grades of workers. The sterling balance of India in the United Kingdom, which will be about £1,000 millions by the end of 1944, is now so large that the Government of India could have no difficulty in providing for all the advanced students or trainees it might wish to send for many years.

In order to ensure that facilities are available in the United Kingdom for the adequate reception of such people when the time comes, I strongly suggest that representatives of the Indian universities and other interests concerned should proceed to the United Kingdom as soon as possible in order to make preliminary arrangements with the authorities here. There is plenty of goodwill in British institutions, and (as I have ascertained) in British industry, towards the idea of receiving able and carefully selected young Indians for research, for advanced study, or for works experience : but the universities, medical schools, technical colleges, and most research laboratories will be overwhelmed, soon after the war, with applications for admission from people whose

claims it will be *hard to resist.*' Unless arrangements are made in good time disappointment will certainly result. Moreover, for several years vacancies in British institutions for Indian postgraduate and research students will be eagerly sought, and it will be necessary to ensure that they are given to the right people, qualified both by intellectual standard and by character to make the best use of them. It is particularly important, in order to gain goodwill for the plan, that the early groups should be most carefully chosen. There is bound to be a certain reluctance to give vacant places to young people whose chief assets may be the financial resources of their fathers, or whose main purpose may be merely to get a higher qualification as a step to advancement in a profession. If available facilities, which are certain to be limited for some years, are to be used to the best advantage, and if the results are to be of the greatest future use to Indian science, medicine, technology and industry, the most careful selection should be made in India of those who are to be given an early opportunity of working abroad.

In the case of medicine and to some extent of engineering it might be best at first to pay special attention to those young men who have served with the Indian Forces. Their wider experience, and the fact that they will have played the same part during the war as most of the young men beside whom they would work in the United Kingdom, would allow them to fit in more quickly and easily : and their selection would be easier because their records would be known. No doubt for most of the rest the Joint Universities' Board and the research organizations of India together could set up a suitable body for the selection of candidates for a period of advanced study or research abroad. In view of the great future importance to India of biology, in connexion with agriculture, food, fisheries, pest control, etc., attention should not be concentrated unduly on the physical sciences.

Very many of those who come to work in the United Kingdom would probably have arrangements made for them personally, by their teachers or directors ably have arrangements made for them personally, by their teachers or directors in India, directly with the heads of research establishments, etc., in Great Britain. If, however, an Indian Scientific Office were established in London it would probably be wise for this Office to be notified of all scientific workers other than undergraduates arriving in Great Britain and to make contact with them. For those for whom no definite provision had been made, or for whom some change was required, the Indian Scientific Office, in consultation with the Education Department at India House, could probably make the necessary arrangements.

(4) AN INDIAN SCIENTIFIC OFFICE IN LONDON.

If scientific contacts and exchanges are to be extended between India and the United Kingdom, and so with the rest of the Empire and other countries, it will be advisable to set up in London an Indian Scientific Office to which would be attached (say) five specialists to deal with scientific matters relating respectively to agriculture, defence, engineering, industry and medicine. This would follow a recommendation of the British Commonwealth Science Committee of the Royal Society, *viz.* :—

> That a suggestion be made to the Governments of the various English-speaking countries that they should consider the possibility of maintaining permanent scientific representation in London and possibly also in other capital cities of the English-speaking world.

The President of the Royal Society has suggested to the Secretary of State for India that the Society might set up a special committee of Fellows interested in Indian affairs, for the purpose of advising the Indian Scientific Office, the India Office, or the Office of the High Commissioner for India on any special

matters desired. Such advice would have continuity as well as authority, which is more than could be obtained from *ad hoc* committees improvised at intervals for special purposes. To take a single example, appointments to various important scientific posts in India will fall to be made from time to time, particularly in the next few years. Some of these will require men of the highest scientific standing. If these are available in India, so much the better ; when they are not, and it may be some years in certain subjects before they are, it will be unwise not to offer appointment to the most eminent persons available. Such people do not usually answer advertisements : they have to be sought out and negotiations have to be undertaken with them. An Indian Science Committee of the Royal Society, with expert advice from other Fellows when required, could provide the special knowledge needed in making such nominations to the High Commissioner. A standing sub-committee of this body might afford general scientific assistance to the Indian Scientific Office.

(5) SCIENTIFIC LIAISON WITH THE UNITED STATES.

There are many practical problems, to the solution of which scientific methods can contribute, which are common to India and North America. For example, the United States has in recent years had considerable and disastrous experience of the consequences, in dust, erosion and floods, of improvident exploitation of the land : and much thought and research have been devoted with considerable effect to the problem since 1935, when the Soil Conservation Service of the United States Department of Agriculture was established. A similar problem exists in India. Rural health and nursing services have been highly developed in the United States, under conditions, particularly in the Southern States, which are not so remote from those of India. The control of pests is another common problem. Irrigation and hydro-electric developments are matters of first importance in the West, as they are in India. These are typical examples : there are many others.

In the United Kingdom now scientific men are in extremely close and familiar contact with their colleagues in the United States, and all information relating to the war is shared between us. Even before the war the mutual knowledge and regard of scientific people in Britain and America were probably higher than of any other groups. I have no doubt that the scientific community in the United States would be glad to establish similar relations with their colleagues in India. Considerable advantage would accrue to India from closer contact with the experience of the United States, particularly in dealing with such problems as the above.

Since 1941 there has been a British Central Scientific Office (B.C.S.O.) in Washington through which the mutual sharing of scientific and technical information is conducted. This Office acts now for the Dominions as well as the United Kingdom, and there are representative groups of them all there. Americans have been extremely appreciative of the work of the B.C.S.O. and it is hoped that in some way or other its activities may be continued after the war. Scientific visitors or missions to the United States have found its help, its experience and its files of information most valuable. I have discussed with the present Director of the B.C.S.O. the possibility of attaching representative Indian scientists to the Office, and he assures me that they would be extremely welcome. I strongly recommend that a mission be sent there, representing scientific interests in agriculture, industry, medicine and war equipment : and that India should take part in the future in whatever organization may grow out of the B.C.S.O. after the war.

If and when an Indian Scientific Office is established in London there will be further opportunities of scientific liaison with the U.S.A. (and the

Dominions) through their scientific representatives here. There can be no doubt of the cordiality with which the Americans would co-operate in closer scientific liaison with India, or of the good which would accrue to India from more familiar contact with American (and Dominion) knowledge and experience.

(6) A RESEARCH BACKGROUND IN MEDICAL EDUCATION.

Although the purpose of my visit to India was not related to any special branch of science, it was natural, as a physiologist, that I should be given special opportunities of seeing hospitals, medical colleges and departments of medical science. It would be difficult except at very great length, and improper without much more careful study, to report in general on the state of medicine, public health, medical education, and research in medicine and the medical sciences : and in any case the Health Survey and Development Committee is now examining the whole situation in these respects. Certain impressions and conclusions, however, have been forced on me during my visits and discussions, which I do not think would be altered by a fuller survey.

(A) *Research in the pre-clinical sciences.*—Taking these as anatomy (including histology), pharmacology, physicology (including biochemistry and biophysics) and normal psychology, the standard in the medical colleges seems to me on the whole to be unduly low. Routine teaching is done to a moderate standard limited by staff, space and equipment, but there is little significant research. Biochemistry is probably the best, because of its association with chemistry rather than medicine, because of its relation to agriculture, nutrition and industry, and because it is impossible to employ underpaid medical practitioners to teach it.

The pre-clinical sciences are the basis of the scientific study of medicine and of what is now called ' Clinical Science '. If the pre-clinical sciences are weak it will almost inevitably follow—and it has followed in India—that clinical research and the standards of higher medical thought and education will be in a bad way. This is clearly brought out in the Report of the Interdepartmental Committee on Medical Schools (' Goodenough Committee '), recently published (H. M. Stationery Office, 1944), copies of which ought to be available in every medical college in India. The Report (p. 79) goes on to emphasise the wider importance of these subjects :—

> ' It is possible, in view of the increasing national interest in such matters as nutrition, physical education, agricultural and veterinary education and the focussing of more attention on the maintenance of health, that the future may bring anatomy and physiology into wider contact with the life of the community. It may well be that every member of the community should learn some elementary anatomy and physiology from teachers adequately trained in these subjects. Such possibilities indicate the importance of increasing the present recruitment of junior workers'

and, it is added elsewhere, of improving their salaries, status and conditions. These comments apply equally to India.

There are many medical colleges in India : there are many physiologists anxiously concerned about the prospects of their subject : but India is making, as yet, little significant contribution to it. The reasons are not far to seek :—

(a) The departments of physiology are grossly understaffed. Usually there is a professor paid a full-time stipend and often labouring with devotion : but the rest of the staff are apt to be busy medical practitioners who, for a meagre part-time salary, come in and take a turn at teaching the classes. ' The habit of running departments of physiology (and the same is

true of anatomy) 'on the cheap', by employing as teachers people whose minds and interests are bound to be largely elsewhere, has had a disastrous effect on the subject. No real improvement can take place until most members of the staffs of the pre-clinical departments hold full-time appointments, reasonably well-paid, in which research as well as teaching is regarded as a normal duty.

(b) In Great Britain and the United States many of the most important contributors to physiology have come in from other subjects—physics, chemistry and zoology. In India little encouragement has been given to such people, no doubt partly because, having no qualifications to earn their living by medical practice, they would require fulltime salaries. The result is that in India physiology has not developed as an independent science, but has remained purely an adjunct of medical education.

(c) The physiology departments have been starved of space, of modern equipment for research and teaching of technical assistance and of funds available for purposes of research.

(d) Owing to (a), (b) and (c) no great school of physiology has ever developed in India from which teachers and research workers could go out to other schools and raise the standard all round. That is what happened in other countries. In the United Kingdom, for example, modern physiology started from Sharpey at University College, London; from there his pupils went to Cambridge, Edinburgh and Oxford, and thence their pupils to almost every school in the country. In those four centres, in particular, physiology has held a proud and independent position as a science in its own right, of the same intellectual standing and importance as any other science. A necessary step in the development of scientific medicine in India will be to start off one first-class department of physiology at which teachers and research workers of a new standard and a new outlook will be reared and thence sent out throughout India. That, however, applies to most other subjects connected with medicine and is referred to again under 'AN ALL-INDIA MEDICAL CENTRE'. (Section 7 below).

The foregoing remarks refer particularly to physiology: but they apply almost equally to anatomy and pharmacology in the medical colleges; and there is little provision for psychology. Biochemistry is in rather better case because it has developed a certain independence of medicine, has had a special part to play in relation to nutrition, and has connexions with agriculture and industry. It will be a pity, however, if biochemistry is encouraged to develop mainly as a branch of chemistry, in order to avoid the narrowness and penury of the medical connexion. It should be just as closely in touch with physiology, pathology and medicine as with chemistry, agriculture and industry.

(B) *Research in pathology and bacteriology.*—In the medical colleges much the same criticism applies to these subjects as to the pre-clinical sciences. The departments are understaffed and ill-equipped and most members of the staff are mainly occupied in earning a living in other ways than by teaching and research. Consequently the scientific standing of the departments is generally low. The scale of staffing required by the Division of Pathology in a University Medical Centre is estimated by the Goodenough Committee (Report p. 291) to be as follows, all full-time:—

4 departmental heads (morbid anatomy, bacteriology, chemical pathology and clinical pathology).

4 lecturers.

4 resident assistants.

8 demonstrators.

To this is added about 30 members of technical, assistant, or secretarial staff. It would be quite impossible in India at present, even if funds were available, to staff the Divisions of Pathology of the medical colleges on that scale : sufficient people of the right calibre and experience are not available. This makes it the more necessary, (a) as soon as possible to send able post graduate students abroad for higher training, and (b) to establish some centre in India at which pathologists can be trained to a much higher standard than at present.

There are of course a number of other institutes, outside the medical colleges, in which work of the very highest quality has been done in these subjects : e.g., the Haffkine Institute at Bombay, the King Institute at Madras, the School of Tropical medicine at Calcutta, the Central Research Institute at Kasauli, the Malaria Institute at Delhi and various others. These are referred to under 'MEDICAL RESEARCH' (Section 8). India has a very high tradition in connexion with tropical medicine : but the work has been done mainly outside the departments of the medical colleges, which remain largely adjuncts of medicine for routine examination and teaching. Researching can reproduce itself only if it is in contact with students and young graduates.

(C) *Research in clinical science.*—It is scarcely an exaggeration to say that practically no research work of any significance in clinical medicine is yet done in Indian medical colleges. The amount and variety of clinical material are enormous : there is the most urgent need to advance scientific knowledge of the clinical aspects of many diseases : there are plenty of keen, able young people who, given the training, the opportunity and a reasonable salary and status and prospects for their future, would be glad to devote their lives to the advancement of medicine by teaching and research. At present, however, in India, possibly even more than elsewhere, success in medicine is measured by the size of one's income and the number, wealth and importance of one's patients.

Under the present system there are very few full-time teachers and research workers in the clinical subjects, and there are no fulltime medical, surgical or gynaecological units. Busy and successful practitioners usually control the teaching and stand out as the ideal to be aimed at by the medical student. Their hearts are bound to be mainly in their private practices. It seems to me imperative that full-time clinical Units should be started in all Indian Medical Colleges, in medicine, surgery and gynaecology, as soon as teachers and research workers of a high enough standard are available : and that the full-time professorial heads of these Units should control the use of the hospitals and laboratories for all purposes of education and research.

The scale of staffing of the Divisions of Medicine, Surgery, and Obstetrics and Gynaecology, in a University Medical Centre, is estimated by the Good-enough Committee (Report p. 292) : for example in the Division of Medicine :—

1 professor, full-time.
2 readers, full-time.
8 physicians or assistant physicians, part-time.
10 assistants or registrars, full-time.
10 pre-registration house-physicians, full-time.

I realize that nothing on this scale could be done in India at present, except at one or two Centres . there are not enough people of sufficiently high standard available, and probably a good deal of opposition to the full-time principle would be met, as in the United Kingdom and America, from existing interests. Moreover, its universal adoption is bound to be very expensive, and medical education in India is under the Provinces and States, not under the Central Government. It, however, it started gradually in various centres, as opportunity

occurred and staff became available, its obvious advantages would be seen and the principle would tend to spread. A start might be made by the Medical Research Board (proposed in Section 19 below) setting up complete, full-time Clinical Research Units in one or two centres.

(7) AN ALL-INDIA MEDICAL CENTRE.

In all the subjects of a medical course, in laboratory as well as hospital, the crying need in India is for full-time workers, capable and well-trained, able to devote their lives to the advancement of the science and practice of medicine by education and research. It has become almost a cliché to say so, but in no other subject than medicine is it so necessary that education should be given in a research atmosphere. Each patient presents a problem, each diagnosis is a theory, each treatment an experiment, often an expensive and painful one : and it must seem to anyone of scientific upbringing almost a crime that the results of nearly all these costly experiments go unrecorded. In the right research atmosphere this would not be so, but in that of an ordinary general hospital, with a very part-time staff and no provision, e.g., by an almoner's department, for ' follow-up ', it literally is. How can medical education produce a scientific attitude of mind in such circumstances ? In fact it very seldom does.

Far the most effective way of producing a change in all this would be to set out deliberately to create teachers and research workers of a new kind, people who would devote their lives to the single object of advancing in India the art, science and practice of medicine. For this purpose a great All-India Medical Centre should be established, an ' Indian Johns Hopkins ', staffed in all departments by the ablest people available anywhere, employed full-time and adequately paid. The students of the All-India Medical Centre should be highly selected ones, preferably with good degrees in arts or science as a start : and since a large proportion of the most desirable students cannot meet the financial cost of a long training in medicine, all who require help should be given it in the form of scholarships or bursaries. (See the Goodenough Committee's Report, pp. 100—104, particularly paragraph 26.)

This last point is a very important one and can be put in this way. There is little doubt that the medical profession does not tap much of the best ability of any country, partly because medicine, as usually practised, does not appear to offer the same intellectual interest, or challenge, as science does, but largely because of the cost of a medical education and of maintenance during it. Many medical students in all countries are in fact of rather inferior intellectual quality. The importance, however, to any country of a really high type of doctor is great : and the importance of a high type of medical teacher and research worker is very great indeed. The intention of the All-India Medical Centre would be to produce the future leaders of Indian medicine and public health, the teachers and research workers. Now in industry it is recognized that the cost of any product depends upon design, manufacture and raw material. The cost of raw material is often so small a part of the total expense that it is folly to use anything but the best if a high-class product is required. The total cost per student in All-India Medical Centre is bound to be high : if by liberal scholarships amounting to (say) 10 per cent. of the total annual cost, the final product could be made on the average 50 per cent. better, then obviously the scholarships are money very well spent. That I believe is exactly the situation. The best possible students should be brought into the Centre regardless of all other considerations—financial, racial, religious, political, provincial and so on. If any reason whatever were accepted for admission other than ability and character the project would lose at once a large part of its value.

The *All-India Medical* Centre should be genuienly an All-India affair. It might be thought best to establish it in some great industrial city : but the need to avoid communal, political, inter-provincial and inter-state difficulties and rivalries is so great, the need to avoid jealousies and conflict with existing interests so evident, that I have been convinced that the Centre should be established in the Capital City of India. Delhi University is growing in stature and importance : there are many scientific institutions in and around Delhi : Delhi is the meeting ground of many scientific and medical interests : Delhi will probably become the headquarters of a future national academy of sciences and of other specialist national scientific bodies : and air transport in the future will make communication with other parts of India vastly quicker than at present. If the All-India Medical Centre is to play the national part it should in advancing medicine and public health, and to gain the international repute which will put Indian medicine ' on the map ' and attract first-class teachers and research workers from any part of the world, then I think it must be given the national recognition and status which is possible only by its establishment at the Capital of India.

The project of an All-India Medical Centre is bound to be very expensive. Well designed air-conditioned buildings and the best modern equipment and libraries, though important, will represent only a small part of the whole cost The chief expense will be that of the full-time staff required. Supposing recurrent expenditure to be met from interest on invested funds, an approximate estimate of the total capital required, allowing for interest of 3.3 per cent. is about Rs. 7 to 10 crores. It should be possible to obtain a considerable part of this from Indian and other benefactors and from international foundations. If it proved possible to build, equip and endow the Centre entirely from voluntary gifts, the freedom and independence so given to it would greatly strengthen its hand against eventual political or other pressure, to compromise with which would inevitably lead to a lowering of standards. *An All-India Medical Centre might be a very fitting national memorial to the Indian Forces after the war, a sign of the national determination that nationhood and national pride shall mean the welfare of the people as a whole.* For better health is the first need of India.

As regards the running cost of the proposed All-India Medical Centre, a substantial contribution could be obtained by providing special accommodation for private paying patients, as in many American University Hospitals. Since first-class medical and surgical treatment would be available, many wealthier patients would probably prefer the Medical Centre to a private nursing home. Their fees would go entirely to the Medical Centre, not to the individual physician, surgeon, bacteriologist, pathologist, etc.

It would be an advantage, not a disadvantage, to the Medical Centre, to have patient of all, not merely of the poorer, classes : and the fees could be adjusted, as at the Mayo Clinic, Rochester, Minn., to the incomes of the patients. Moreover, the goodwill and interest of influential patients who had benefited by treatment at the Medical Centre, would be of value in forwarding the principles and ideals for which the Centre was founded. The tendency in America to use the University Hospitals for private patients in this way has been strong in recent years, and the same tendency is evident in the United Kingdom. It is one to be encouraged in India.

A Malaria Hospital.—As part of the All-India Medical Centre there should be a special hospital for the clinical study of malaria. Malaria in India is Public Enemy No. 1. The discovery of modern chemical ' repellants'

like D.D.T. has given hope of far more effective attack on the malaria mosquito. Even so, there are many hundreds of millions of people throughout the world who already have the malaria parasite in their systems, and it seems unlikely that the disease will be abolished altogether except by learning how to cure it in human patients, to eliminate the malaria parasite from their bodies so that the mosquito cannot carry it to others. The possibility of an effective cure is not yet apparent, but the developments of chemo-therapy in recent years have been so rapid and astonishing that it would be folly not to reckon with the probability that some chemical agent not yet known, or not yet properly tried out clinically, may be found to be effective.

If this line of attack is to be successful it will require the most careful clinical and laboratory studies on malaria patients subjected to various treatments and therapeutic agents, and an elaborate ' follow-up ' system to find out whether apparent cures are permanent. The clinical staff of the Malaria Hospital would need to be in close and continual touch with chemists engaged in the organic synthesis of new agents, with pathologists, biochemists and immunologists. A hospital of about 200 beds would be required, with special laboratories.

The most suitable patients might be soldiers of the Indian Army, who, on leaving hospital, would return to their duties under conditions in which ' follow-up ' would be easy, re-infection could be avoided and conditions of health and nutrition controlled.

Nowhere in the world, to the best of my knowledge, is there a hospital specially devoted to the clinical study of malaria. India has played a large part in the study of tropical disease, particularly of malaria, and it would be appropriate that she should continue her contribution to world medicine in this way.

(8) MEDICAL RESEARCH.

Medical reasearch in India, by a long tradition, has been done in the main at special institutes, usually quite unconnected with the medical colleges and universities. The research department of the Indian Medical Service, in adjustment with Provincial and State authorities, has been mainly responsible for these ; and the Indian Research Fund Association has provided research grants and salaries. Very distinguished work has been done in them, particularly in tropical medicine. Among them are :

The Central Research Institute, Kasauli

The School of Tropical Medicine, Calcutta

The Haffkine Institute, Bombay

The King Institute, Madras

The Malaria Institute of India, Delhi

The Drug Research Laboratory, Jammu, Kashmir

The All-India Institute of Hygiene & Public Health, Calcutta

The Nutrition Research Laboratory of the Indian Research Fund Association.

There is an obvious advantage in placing talented research workers in a situation where they need not be unduly burdened by teaching and routine : conversely, however, there is disadvantage in isolating medical education and the clinical work of teaching hospitals from all contact with research. Moreover, it is a serious loss to many research workers to remove them from the stimulus of young inquiring minds and from the general scientific contacts of a university.

The process, therefore, of setting up separate institutes in India for medical research has probably gone far enough : and some advantage would now result from bringing existing research institutes, where practicable, into closer contact with the medical colleges and higher medical education. The National Institute for Medical Research and the Lister Institute in London are treated for purposes of postgraduate study as Schools of the University of London. Similar arrangements could be made in India. In setting up new institutes for medical research in India, or in promoting new schemes for research units, the advantage should be borne in mind of associating them with appropriate existing medical colleges and hospitals.

In the United Kingdom the Medical Research Council (M.R.C.), founded in 1914 and working under the Lord President of the Council, has had a very great influence in promoting new knowledge of medicine and allied sciences. It has acted mainly by organising, encouraging and financing research work in existing university laboratories and medical schools. The National Institute for Medical Research belongs to the M.R.C. but its activities represent only a fraction of the work done under the Council's auspices. The M.R.C. has an extremely free hand in the use of the funds allocated to it, and its plans have never been seriously held up for lack of them. It is not directly associated with the Ministry of Health, and there is no suggestion today that it would be better placed under that Ministry. It is able to undertake the most fundamental work of long-range character, but it is equally able to tackle emergency problems when they turn up. The governing Council consists mainly of eminent research workers and experts in medicine and public health.

The Indian Research Fund Association (I.R.F.A.) plays a rather similar role in India. Its funds, however, are very scanty, though it is not hampered in the application of them such as they are. The I.R.F.A. is an independent registered body deriving its funds, not from an extra-departmental Minister with a special care for Research, but from a 'user' department (Education, Health and Lands). Because of its poverty it cannot take the same broad view of its functions as the M.R.C. does, for example, to maintain even a single clinical research unit in one of the Medical Colleges would be financially out of the question until ampler funds are available.

(9) VITAL STATISTICS AND POPULATION

It is greatly to be regretted that the Census of India of 1941 was not completed or its results fully worked out. The population of India is increasing now very rapidly, and is likely for some time to increase even faster as public health and nutrition improve and the present appallingly high mortality diminishes. All future planning of the nation's resources, and of the scale and direction of national development, depends on the size and age distribution of population at the dates considered. Since the trend of population can be foreseen by analysis some time before it is apparent in gross figures, it is very desirable that the data for analysis should be available, and that prediction should be carried out on various probable assumptions as to the effects of improvements in public health and nutrition on the mortalities at different ages. With any reasonable assumptions as to such effects, the size and urgency of the task of national development will be apparent, particularly in regard to food and agriculture : and it will be realized that every improvement in health and nutrition ought to be accompanied by some corresponding effort to educate the people, particularly the women, to some sense of responsibility in reproduction.

It is commonly argued that a rise in the standard of living will lower the birth rate*; so for India all that needs to be done is to raise the standard of living and all will be well! So far as this pious belief does not rest on the use of an ambiguous and misleading term, the crude birth rate (which depends as much on longevity as on fertility!), it is probably quite untrue that the net reproduction rate falls as the standard of living rises—until at least the standard of life has risen so high that education has led to sophistication, and all kinds of aspirations, emulations and desires have displaced the urge to reproduction. At any rate a quantitative comparison of different groups, and in different regions, of similar people at different levels of prosperity and nutrition could determine whether the first effect of a rising standard is likely to be a fall, or a rise, of the rate of reproduction. The fact that the birth rate and the net rate of increase in the Punjab are significantly higher than in India as a whole suggests that the first effect of a higher standard may in fact be a rise.

A similar statement frequently repeated is that 'industrialisation' will lead to a fall of 'birth-rate'. In England and Wales throughout the nineteenth century, the age of industrialisation, the net rate of increase—in spite of heavy emigration—lay between 12 and 18 per cent. per 10 years, averaging 14 per cent. Whether the present downward trend in the United Kingdom is due to 'industrialisation', or to a variety of other causes, can be argued about, but at any rate it did not begin for a whole century. It would be possible by collection of data and analysis to find out, roughly at least, what effect industrialisation is likely to have in India on rate of increase of population: though it must be remembered that the population of India is bound to remain predominantly agricultural for a very long time.

The crude death rate is well known to be an entirely misleading criterion for the comparison of mortality in populations with different age distributions. For example, the crude death rate in India is about twice that in Britain, but the mortality at any specified age up to 55 in India is 4 to 8 times that in Britain. The population of India, owing to the higher mortality, is much younger than that of Britain and the mortality of a younger population (other things being equal) is less. To compare the crude death rates is not a comparison of like with like. The decision of where the available effort for national development should be directed depends largely upon a public understanding of the actual facts and probable trends of morbidity, mortality, reproduction and population. It is greatly to be hoped therefore that the Government of India will ensure that all the necessary information is obtained, analysed and published; and that a careful, objective and intelligible statement is made available for the public, to assist them in drawing conclusions as to where the most urgent needs of India lie for national betterment. I understand that an expert Committee has been set up by the Government of India to explore the subject of population: presumably it could undertake the wider task suggested above, and—remaining in being—could bring it up to date from time to time.

(10) AGRICULTURAL RESEARCH.

Agriculture is by far the most important industry and interest in India, and a great expansion of it is necessary; *first*, to provide more adequate nutrition for the present population of rather more than 400 millions; *secondly*, to

*Recorded birth rates in India appear to be too low by about 2-3 per thousand. In the absence of significant emigration or immigration, successive census figures should be calculable from one another by means of differences in intervening years between birth and death rates. In order to get the correct figures, higher differences must be used. Presumably about 7 per cent. of births are not recorded.

anticipate the food requirements of an increase of population which at present is about 15 per thousand per annum, and is likely to become appreciably higher as public health measures and nutrition improve; and *thirdly*, to provide for expansion of crops required for industry and export. Unfortunately limitations of time, together with my own lack of expert knowledge of agriculture, made it impossible for me to gain a first-hand acquaintance with the very considerable effort which is being made in India in agricultural research—a greater effort than is yet being applied in any other scientific direction. Some reference, however, is necessary here to so important a subject.

Agricultural reasearch in India is carried on :

(A) in institutions maintained and controlled by the Central Government :

(B) in agricultural and veterinary departments of Provincial Governments and leading Indian States :

(C) by All-India Committees for Cotton, Jute and Lac, and the Imperial Council of Agricultural Research.

Under (A) come :

(1) The excellent *Imperial Agricultural Research Institute* at New Pusa outside Delhi, with separate sections of Botany, Mycology, Entomology, Soil Science and Agronomy. Originally it was established in 1905 at Pusa in Bihar, but was transferred to Delhi in 1936. The Institute has four sub-stations, at Pusa in Bihar, at Karnal in the Punjab, and at Coimbatore (for sugar-cane breeding) and Guntur in Madras. The annual grant, at present, is about Rs. 8½ lakhs.

(2) The *Imperial Veterinary Research Institute* at Mukteswar in the U.P., with some sections at Izatnagar ; the annual grant is about Rs. 10¾ lakhs.

(3) The *Imperial Dairy Research Institute* at Bangalore, with an annual grant of about Rs. 3 lakhs.

(4) The *Imperial Institute of Sugar Technology*, with an annual grant of about Rs. 3¾ lakhs. I understand that the Government of India is considering a proposal to constitute an Indian Central Sugar Committee on the lines of the Indian Central Cotton Committee (see below). The Committee would receive a grant from the Central Government from the cess levied on white sugar produced in British India. If this Committee is formed the administration of the Imperial Institute of Sugar Technology would be handed over to it.

The grand total under this heading (A) is about Rs. 26 lakhs annually (£200,000).

Under (B) the facilities for research in the Provinces are more highly developed for crops than for animals and a large variation exists between different provinces in the effort made in research. In the Punjab an elaborate organization has been created : in Orissa and Sind financial considerations are said to prevent any substantial contribution. The same variation is true of the States : Hyderabad, Mysore and Baroda have fairly well developed institutions but the smaller States have very little ; though 25 of the smaller States of Central India have set up a joint concern called the ' Indian Institute of Plant Industry ', financed by *pro rata* contributions from the constituent States and subsidised by the Indian Central Cotton Committee for research on breeding problems of cotton in that tract.

Under (C) come :

(1) the *Indian Central Cotton Committee*, constituted by statute and deriving its income from a cess on raw cotton, normally about Rs. 7 lakhs

annually. The Committee maintains a Cotton Technology Laboratory at Matunga, Bombay, and a sub-station at Indore with the Indian Institute of Plant Industry referred to above. The Committee deals with all problems relating to the production of raw cotton, its processing and supply.

(2) the *Indian Central Jute Committee*, deriving its annual grant (about Rs. 4 lakhs) from the Central Government, and maintaining a technological laboratory at Calcutta and a farm at Dacca.

(3) the *Indian Lac Cess Committee*, deriving its income, normally, about Rs. 3 lakhs, from a cess on the export of lac, and maintaining a technological institute at Ranchi.

(4) the *Imperial Council of Agricultural Research* (established in 1929) which is responsible for all research on crops and animals which has not been handed over by the Central Government to special committees. Its income is derived from a cess levied on the export of certain agricultural commodities, being normally about Rs. 14 lakhs, but at present—owing to the war—considerably below that figure. The secretariat is maintained by the Government of India. The I.C.A.R. has representatives of Provinces, States and a variety of interests: it appoints scientific and commodity committees. It does not, in practice, undertake any research work directly, but finances special projects at appropriate institutes throughout India.

The grand total under this heading (C) is normally about Rs. 27 lakhs (£200,000).

Excellent work is being done in India in agricultural research : and it could obviously be greatly extended, particularly by undertaking large scale trials, if funds and scientific staff were available. The total expenditure in India for research in agriculture, in all regions and subjects together, must be of the order of £500,000 (say Rs. 70 lakhs) annually. This is about two thirds as much as was spent in Great Britain before the war on agricultural research, in a country of one-eighth the population and one-twentieth the area; and in Great Britain it is being urged (*A Scientific Policy for British Agriculture* : Parliamentary and Scientific Committee, 1944) that ' expenditure on agricultural research should be raised to at least £3 millions per annum '. Great and effective as the effort in India has been in agricultural research, the amount spent on it is still only about one quarter of an anna per inhabitant per annum, one-tenth of an anna per acre of the total area. India is not so poor that a considerably greater effort could not be devoted to research in its greatest industry and its most important interest. Recent announcements, in fact, of a plan for increasing agricultural production by 50 per cent. in 10 years, by 100 per cent. in 15 years, suggest that steps are already being taken to that end.

(11) SURVEYS AND NATURAL RESOURCES.

The material resources of India are very great but most inadequately known. The Geological Survey of India was founded in 1851, the Botanical Survey in 1889, the Zoological Survey in 1916. The Geological Survey is active and has done distinguished work under distinguished directors, but is quite inadequately staffed for the enormous task it has to accomplish. The Directorship of the Botanical Survey has been in abeyance for 7 years, and very little financial aid has been available for 14 years for botanical field work. The Zoological Survey for many years has done practically no field work and its activity has been restricted to maintaining a museum : this followed a report of a ' Retrenchment Committee in 1931.

Fishery research has been done in various small provincial stations : it also has a place under the Zoological Survey. The effort devoted to it, however, has been quite inadequate when its importance is considered. The fish supplies of India, from fresh water and sea, are potentially very great, and could make a substantial contribution to national nutrition. If, however, the fisheries were exploited without careful scientific survey and control, their present yield would be less than it need be, and their future productivity might be gravely prejudiced.

I gather that a plan exists for two national Fishery Research Institutes, one for sea-fisheries at Bombay, the other for fresh-water fisheries near Calcutta. I would most strongly recommend that this plan be proceeded with, that Directors be appointed as soon as possible and that staff be collected and trained in preparation for the time when buildings, ships and equipment can be provided. The possible contribution of fishery research to national welfare is very important : the magnitude of this contribution, and the speed with which it becomes available, will depend at least as much on first-class staff and ideas as on building and equipment, and there is no need of delay in collecting and training staff and making plans.

The case for biological research stations for fisheries has been well stated by Dr. H. Srinivasa Rao in a Presidential Address to the Zoological Section of the Indian Science Congress in 1942.

In deciding on the future of the Botanical Survey, that of the Royal Botanic Gardens at Sibpur, Calcutta, with the great Herbarium there (which is really the national herbarium of India), should be considered too. Both of these latter have been maintained hitherto by the Government of Bengal. It would be natural to associate them, by arrangement between the Government of Bengal and the Central Government, with the Botanical Survey. The Botanical Survey, restored and re-invigorated, should be able to play an essential part in long range plans for agricultural development.

As regards the Zoological Survey, the enormous wealth of the Indian fauna demands something more than a museum. Apart altogether from the duty of any great country to promote the scientific knowledge of its own resources, such knowledge could not fail to have an important practical bearing on Indian agriculture and industry.

As regards the Geological Survey, I gather that there is a serious shortage of competent and experienced Indian geologists and of university departments to train up younger ones. Geology nowadays requires also men trained in modern geophysical methods and there is a strong move in the United Kingdom now to provide more funds and facilities for training and research in geophysics. Some of the excellent young physicists now available in India could be diverted with profit to this field. The knowledge of Indian mineral resources is still sketchy ; which is a hindrance now in the war-effort of the country and will be continuing handicap in post-war development. Moreover, geology impinges on such important subjects as water supplies and irrigation, soil erosion and land maintenance. It is clear that considerably increased effort should be devoted to geological work of all kinds in India, and that the training of the personnel required should proceed as early as possible.

Modern statistical methods have a considerable application to the survey of national resources of all kinds, as they have also to ' quality control ' of industrial production. Fortunately there are distinguished statisticians in India, and a number of workers experienced in ' sampling ' methods : and the Indian Statistical Institute is a focus of important activity. For the rapid post-war development of the country a full detailed knowledge of natural

resources, agricultural production, etc., will not always be quickly available, and statistical methods of the requisite degree of significance will have to be employed. Emphasis, therefore, must be laid in the coming years on the need to increase the number of trained statistical workers, particularly by facilities for advanced study abroad ; and on giving them opportunities for the fuller use of their methods in studying national resources and needs.

In the discussion of national resources as a whole other important subjects need obviously to be considered, such as water-power, water supply, forests, soil, population, etc. It is suggested below under A CENTRAL ORGANIZATION FOR SCIENTIFIC RESEARCH (Section 19) that a special Research Board should be set up on ' Surveys and Natural Resources '. This would provide the most effective means of obtaining, maintaining, and making generally available the accurate quantitative assessment of natural resources which is essential to national planning.

(12) INDUSTRIAL RESEARCH UNDER THE GOVERNMENT.

The foundation in 1940 of the Board of Scientific and Industrial Research represented a very notable step forward in the organisation of Government Science in India : its full influence has not yet had time to be felt, though already it has produced important results. The example of the Department of Scientific and Industrial Research in the United Kingdom, which—founded in 1916—has attained a very important position and will have an increasing influence as time goes on, indicates the directions in which Industrial Research should develop in India. Financial provision was made in the recent Budget for some of these developments, for Fuel Research and Glass Research, and for National Laboratories for Physics, Chemistry and Metallurgy. Many other projects remain still to be considered, for example for research in food processing and food-pests, in ship design, in aeronautics, in radio, in building, in engineering, in road construction, and in many other subjects : though probably some of these would be taken over by other Research Boards (Section 19 below). Moreover, the question of starting co-operative Industrial Research Associations (of which in the United Kingdom there are already 24), as joint concerns with Industry, remains to be thought out. Some of these co-operative Research Associations in the United Kingdom are already strong and effective agencies : though it is clear that they cannot replace the very important research activities of individual firms.

Further reference to Industrial Research is made in Sections 13, 16, 19 and 21 below.

It will be very important for the Board of Scientific and Industrial Research in India to be in close and familiar contact with the D. S. I. R. in the United Kingdom and with corresponding bodies in the Dominions. Such contact will be warmly welcomed. The forthcoming visit to the United Kingdom of the Director of Scientific and Industrial Research for India with some of his colleagues will give him the opportunity of studying the working of the D. S. I. R. and its establishments, and of planning the machinery of closer collaboration and exchange. The projected Imperial Scientific Conference would allow these contacts to be extended.

One criticism I would make : the headquarters staff, technical and administrative, assisting the Director of Scientific and Industrial Research for India is far too small. With the additional commitments he will now be taking on, his burden, without more help, would become intolerable. He will see in the D. S. I. R. in the United Kingdom something of the magnitude of the task likely to confront him later in India and of the provision made for assisting

his opposite number here : and he will be able to claim more adequate assistance and support when he returns.

Early this year at Oxford, Nuffield College organized two conferences on 'Problems of Scientific and Industrial Research', as a result of which a 'Statement' has recently been published by the Oxford University Press. This statement represents the common ground of a wide range of expert opinion in the United Kingdom ; many of its conclusions might find possible application in India.

(13) SCIENTIFIC RESEARCH BY INDUSTRY.

The Bell Telephone Laboratories in New York of the American Telegraph and Telephone Company employ about 4,000 scientific workers and technicians. At one end of the spectrum, research work of the purest academic type and of the highest quality is carried out ; at the other end, the technical development of processes and equipment through the various stages preceding—and up to—large scale manufacture ; and the spectrum is continuous. The General Electric Company at Schenectady, N.Y., Eastman Kodak at Rochester, N.Y., and many other firms have similar laboratories and facilities.

In Britain research work by industry is not on so magnificent a scale, but a very great effort in fact is made. The research departments of the G. E. C. at Wembley, of B. T. H. at Rugby, of Metropolitan Vickers at Trafford Park, Manchester, of I. C. I., of Burroughs Welcome, of Brown Firth and Co., of Lever Bros., of various engine and aircraft firms, and so on, have made essential contributions to British industry, and lately to the British war effort. In addition to these many private enterprises of individual firms, there are the Industrial Research Associations, 24 in number at present, maintained jointly by Industry and the Department of Scientific and Industrial Research.

In India the Metallurgical Laboratory of the Tata Steel Works at Jamshedpur is probably the nearest approach to the American and British model. There are several industrial laboratories on a smaller scale, supported by individual firms, but mostly for purposes really of testing rather than research. There are no co-operative Industrial Research Associations on the British pattern.

India is still on the whole a poor country : but some of its industries have recently been prospering exceedingly. The way to make prosperity secure is to keep well ahead with scientific research and development. The amount which could possibly be spent on research in India at present is not large, for the number of men capable of doing it effectively in any field is still very limited. Admitting that India as a whole is poor, I feel nevertheless that Indian industry is not yet making nearly the research effort it perfectly well could on its own behalf.

There are things that a Government should do, but there are things that industry should do for itself : and all experience in America and Britain shows that research, pure as well as applied, by firms taking the longer view, earns a very handsome dividend. Where would Eastman Kodak be now had not its whole policy been based for many years on research ? And what might have happened but for research and development applied by Rolls-Royce to aero-engines ? It is no good leaving these things to the Government, or to anyone else. Success goes to the industry that takes far-sighted initiative itself. Taking the lowest view of the matter, research pays—real research : but Indian industry as a whole has not yet appreciated the degree to which it pays.

(14) TECHNOLOGY.

There are various good colleges, institutes and departments of engineering and technology in India, but not sufficient of them as yet and none of the same excellence as many in other advanced countries particularly the U. S. A. (One gathers also that in the U. S. S. R. now there are enormous numbers of students of technology in large and well-equipped institutions.) The subject of technical education in India is dealt with in the Report by the Central Advisory Board of Education (January 1944) : my few remarks, therefore, need be devoted only to the higher education which is associated with research or advanced training.

Among scientific and technical people in the United Kingdom the opinion is widely held that Britain has lagged behind in the provision of facilities for higher education and research in technical subjects. The new Education Act will improve the position in respect of technical education at the lower levels : at the higher levels, however, there is no institution as yet in the United Kingdom comparable in magnitude, in the quality of equipment and in excellence of teaching and research work, with the Massachusetts Institute of Technology at Cambridge, Mass., or indeed with several similar institutions in the U. S. A. The view is held by responsible people that two or three such institutes should be set up, or that existing institutions should be expanded for the purpose, at such centres as Glasgow, Manchester, Birmingham and London.

This being the view held in the United Kingdom, where conditions after all, are not so bad, how much more can we recognize the importance of one or two such institutes or colleges of very high standard in India ? The future of Indian industrial and agricultural development must depend upon the supply of first-class technical brains, trained in an atmosphere both of original research and of practical experience. This requires not only that there should be facilities for technical training at all important centres in India, but that one or two technical institutes of the highest possible standing should be founded, or developed from existing ones (*e.g.*, at Bangalore, where the Indian Institute of Science comes most closely of existing institutions to what is wanted). In these, research work of high quality would be done and practical training given, and the ablest students could be brought up in an atmosphere both of research and of practical realism. The principle is the same as that underlying the proposal of an All-India Medical Centre (Section 7).

The cost will be considerable, but if Indian industry and agriculture are to be developed to the highest level by Indians, and if Indians of the required quality are to staff the new National Laboratories to be built under the Board of Scientific and Industrial Research after the war, then Indians must be trained to the highest level themselves. Nationalist fervour cannot replace first-class scientific ability and technical training.

I have bracketed industry and agriculture together in these remarks. The future of agriculture in India depends very largely on mechanization, land utilization and maintenance, fertilisers, irrigation, transport, roads, food-processing and a great variety of other scientific and technical factors. Agriculture is the greatest industry in India and likely to remain so : the welfare of the vast majority of the people of India depends on it and it is essential to increase its productivity greatly, in order to raise the level of nutrition and to meet the needs of a rapidly increasing population. To bring it into close touch, at a high level of education and research, with science, engineering and technology, would help to ensure that it gains all that is possible from such contacts.

This does not mean of course that agricultural education and research should be *limited* to such places : it means simply that agriculture requires the resources of science, engineering and technology for its full development and should be regarded as providing one of the most important fields of application of these.

One chief purpose of the proposed new Institutes of Technology would be to provide teachers and research workers of high quality for other places. This function also would be similar to that of the proposed All-India Medical Centre (Section 7).

(15) METEOROLOGICAL RESEARCH.

Meteorology is a subject of great importance, both for its scientific interest and for its practical applications. Its connexion with the requirements of the Fighting Services, particularly of the Air Force, and its application to civil flying, have ensured that a considerable effort has been devoted to it recently : and indeed, in India, Meteorology appears to me, within the limits of staff, facilities and equipment available, to have been very well done. It has in fact many other applications than those to flying and the defence services, *e.g.*, to radio, and, in India particularly, to agriculture and to emergency warning of floods.

In the United Kingdom now arrangements have been made for research to be intensified not only on applied meteorology but on its more fundamental aspects. Flying, and modern physical methods particularly those of radio and radar, have opened up new possibilities of research in meteorology, for which India should make a particularly fruitful location. Proposals have been made to the Board of Scientific and Industrial Research for the further development of fundamental research in meteorology in India. These proposals have been accepted and it is hoped that a start may be made soon.

The Meteorological Services of India are administered by the Department of Posts and Air, with, of course, strong attachments at present to the Fighting Services. If a CENTRAL ORGANIZATION FOR SCIENTIFIC RESEARCH (Section 19) is set up in India it would be natural to attach *research* in Meteorology in some way to this, possibly under a joint Committee of the Boards for War Research, Scientific and Industrial Research, Agricultural Research, and Surveys and Natural Resources. It would have much more chance of broad development as a scientific subject under a central scientific organization than in a department concerned only with certain practical aspects of it.

(16) SCIENTIFIC INSTRUMENTS AND EQUIPMENT.

Scientific instruments and apparatus are the basis of all scientific and technical work and of the technical control of many industrial processes. There is very little manufacture of such things in India, at any rate of higher-class products. Instrument manufacture can never in itself, financially speaking, be a large industry, but it is a key one and urgently requires encouragement. Given training and experience Indian workmen have all the natural aptitudes required for the manufacture of scientific instruments and apparatus. A very high standard should be adopted from the start, for second-rate equipment is a thorough nuisance and every wise head of a laboratory or workshop will rightly prefer to pay more for a better imported article if one is available.

The manufacture also of good surgical instruments and equipment is an urgent necessity : a lead has been given in the Ordnance Laboratories at Cawnpore.

Special consideration might be given by the Board of Scientific and Industrial Research to the encouragement of these trades.

(17) THE POST-WAR DISPOSAL OF GOVERNMENT STOCK.

After the war a considerable amount of scientific and medical equipment and machine tools will be available for disposal, much of which would be of the greatest value to scientific, technical and medical laboratories which have been starved of such things for many years. If all this is sold to big interests for resale, those may indeed make large profits but factories and workmen will be put out of employment and essential trades may be lost. It would be far better if a free distribution could be made to university and other institutions of equipment they require. Their available funds then would not be used up, and since the appetite for scientific and workshop equipment grows by what it feeds on the essential trades in these things would be tided over a difficult time and maintained in being.

I suggest that the Government of India should set up a Committee to consider the disposal, when the time comes, of scientific and technical stores of all kinds. One of the most obvious criticisms of the majority of university laboratories in India refers to the poverty of their scientific equipment and the frequent absence of any proper workshop facilities and tools. Considerable help could be given them by free disposal of the stores referred to, at small cost to the Government and without damage to skilled and highly desirable trades.

(18) RESEARCH FOR THE FIGHTING SERVICES.

The present conditions are entirely abnormal, but it is obvious that the existing research organization of the Defence Services in India was not designed for the contingency of India being the base for major naval, military and air operations. Anything which can be done now to improve the arrangements for research in connexion with the Services should be planned, not only for the purposes of the present war but in view of the future necessity, under a new constitution, of an Indian Government taking responsibility for the military, naval and air defences of India, for the design and manufacture of her own war-material and for devising the technical methods of her defence. This should be a major consideration, for without security from aggression self-government sooner or later would prove an illusion. Science has played a very large part in the present war, from fundamental research at the one end to the planning of operations at the other. It will probably play a still greater part in future conflicts—possibly in ways at present not commonly realized. The scientific knowledge and experience required for modern war cannot be improvised quickly, nor can it be purchased from others. A proper scientific organization must be built up within the War Department itself.

As regards the needs of the present war, an obvious weakness has been the very imperfect knowledge in India of what is being done, or has been done, in war-research in the United Kingdom, the Dominions and the U. S. A. The situation in this respect has been bettered recently by a visit to the United Kingdom and the U. S. A. by the Scientific Adviser to the Master General of Ordnance, and by several visits of scientific men for special purposes to India It will be further improved by various scientific missions which the Services are sending to India, and by the visit of Indian scientific men to the United Kingdom this autumn.

There is a corresponding lack of knowledge in the United Kingdom of the scientific resources of India, in men, equipment and facilities, and of the

scientific aspects of war requirements for operations for which India is or will be the base.

This mutual lack of information has been due mainly to the almost complete absence of current personal contact of scientific people in India with their colleagues in the United Kingdom : it has been aggravated by the absence of any sufficient organization in the United Kingdom for keeping India supplied with papers and reports referring to the scientific work which is being done in Britain for war purposes, or of the organizations which have been created for such work. The scientific resources of India, in men, laboratories, workshops, and equipment are not inconsiderable, but nothing near full use of them for the war effort has been made : as operations of war develop from India there will be increasing need of a proper scientific organization on the spot to deal with new problems as they emerge. To refer them all to the United Kingdom is bound to be inefficient, time-consuming and unsatisfactory : to tackle them in India without proper knowledge of what has been done elsewhere will often mean fruitless work and loss of time and opportunity.

The chief scientific and technical organization in India for the Fighting Services is that of the Master General of Ordnance. It is mainly devoted to Inspection, which has increased greatly owing to the enormous increase of the war-production of India. Under the general cover, however, of Inspection, a certain amount of research is in fact, done. Moreover, the admirable Ordnance Laboratories at Cawnpore, only opened in 1943, are capable of a good deal of research. Important ' extra-mural ' research on war problems is done also in a variety of institutions outside the organizations under the Commander in Chief, e.g., in the laboratories of the Director of Scientific and Industrial Research, the Metallurgical Laboratories of the Tata Steel Works at Jamshedpur, the Indian Institute of Science at Bangalore, etc.

There are testing facilities under the Engineer-in-Chief, India, but only for routine matters : there are no facilities at present for engineering research. I was informed that a project is being considered of setting up a Research Unit for work on soil-stabilization, runways, roads, bridges, structures, etc., The work of such a Unit might be of great importance to S.E.A. Command, but it would probably better remain under G.H.Q., India and be tied in with the research organization referred to below.

The R.A.F. in India at present is mainly under S.E.A. Command, and it has organized for itself under the Chief Maintenance Officer the special research and development facilities required. It uses also when suitable the facilities available under G.H.Q., India.

The Royal Navy of the Eastern Fleet until recently had no research organization in India, but I gather that a party has now been sent. Other scientific parties are proceeding shortly to India from the Admiralty for the examination of problems affecting weapons, equipment and personnel. The Royal Indian Navy will no doubt take the opportunity of the presence of these scientific parties from the United Kingdom to set up the nucleus of a scientific organization of its own.

The operational research groups in India are under S.E.A. Command, one for the Army, one for the R.A.F. The Royal Navy had no operational research party in India at the time I left. It would be wise for G.H.Q., India, to ensure that the experience of these operational research groups is not lost to the future War Department of India after the war is over.

There is no doubt that the research organization under G.H.Q., India, needs tightening up, strengthening and coordinating at a higher level. For this purpose last February the late Master General of Ordnance proposed, and

I very warmly agreed, that a new post of Scientific Adviser to the C. in C. should be established, with the full authority of the C. in C. to watch over and coordinate all the scientific activities under G.T.Q., India, including 'extra-mural' work of various kinds. For this post a man of the highest qualifications would be needed, with recent knowledge and experience of the scientific and technical work which has been done in the last few years in the United Kingdom and elsewhere. He would require a scientific and technical staff of his own and he would probably wish to bring with him assistants with similar recent experience. He would need the fullest authority to order the necessary equipment and supplies. He would occupy the position of a Joint Secretary in the Defence Department. This proposal was agreed to by the Government of India. Details presumably will be worked out after an appointment has been made.

The proposed Scientific Adviser to the C. in C., India, would be responsible, with the authority of the C. in C., for watching over and coordinating scientific and technical work now going on under or on behalf of G.H.Q., India, for initiating and planning new work and any new organisations required for it, and for providing scientific and technical assistance to the Operational Research Organization under South East Asia Command in tackling problems for which that Organization has insufficient technical facilities. As an important item in his permanent set-up should be a Board consisting of scientists and engineers, official and unofficial, in various fields (including biology), together with service representatives. This Board would meet only at fairly long intervals : its work would be done chiefly by committees (not too large), under the Chairmanship of the appropriate members of the Board, and consisting of scientists, engineers and service representatives. There would probably be a fairly large number of such committees, and their Chairmen would be encouraged to take considerable initiative in enquiring into matters of importance, in visiting Service and experimental stations, in making themselves acquainted with Service needs and problems, and in starting research as required. The whole of this organization would be very similar to, though on a smaller scale than, that of the Advisory Council for Scientific Research and Technical Development in the Ministry of Supply in the United Kingdom together with its associated committees : these have done most valuable work in the last four years. It would constitute the War Research Board of the Central Organization referred to below in Section 19.

The Scientific Adviser to the C. in C. would doubtless insist on having proper arrangements made for efficient and quick liaison with all allied research organizations in the United Kingdom and elsewhere.

Such an organization as that sketched above, under a Scientific Adviser to the C. in C., would be of permanent value to India under the new constitution which will probably come into being in the next few years. Presumably India will then have a War Minister under whom will come the Indian Army, the Royal Indian Navy and the Indian Air Force, each with its own staff. The War Council would contain the Chiefs of Staffs and officers connected with Training, Supply, etc.: the Scientific Adviser to the War Minister would be a member of the War Council, on the same levels as the others. His direct access to the War Minister, and his equality with the Service members of the War Council, ought to ensure that India in the future does not make the disastrous mistake of underrating the importance of scientific research and technical development in modern war, as has happened too often elsewhere.

If, as suggested under A CENTRAL ORGANIZATION FOR SCIENTIFIC RESEARCH (Section 19), scientific research for India is to be concentrated under a single Minister, it would probably be wise to transfer the system of Board and committee proposed above to the new organisation : the Board

would become the War Research Board. Thus the Scientific Adviser to the War Minister would also be Secretary and Executive Officer of the War Research Board and a member of the Scientific Consultative Committee of the Hon'ble Member for Planning and Development. This would not affect at all the working of the organization under the Scientific Adviser, though he would probably require an Executive Assistant to look after it ; but it would ensure that its work was kept in touch with that of the civil Research Boards, and that the help available through them was fully available for defence purposes.

One special aspect of War Research has been largely neglected until comparatively recently, viz., that connected with the human problems of health, fitness and adaptation in fighting personnel—in relation to the conditions of their service and the equipment they employ. Flying, diving, jungle-warfare, armoured vehicles, tropical conditions, and the skilled and efficient use of modern scientific and technical equipment, on land, in the air, and on and under the sea, all provide special problems affecting the bodily and mental condition of fighting men. During the present war, in the United Kingdom and the U.S.A., considerable attention has been paid to all these matters and more will be paid in the future : the results, moreover, may often be of considerable value in civil life and industry. It is strongly suggested that a *Services Medical and Personnel Research Committee* should be set up in India. Its ultimate position under the proposed new arrangement might be that of a Joint Committee of the War Research and the Medical Research Boards.

(19) A CENTRAL ORGANIZATION FOR SCIENTIFIC RESEARCH

The *Medical Research Council* in the United Kingdom was founded in 1914 and placed under the Lord President of the Council, not under the Ministry of Health. Its executive head is its Secretary who is nominated by the Council itself : both of those who have held this office, Sir Walter Fletcher, F.R.S. and now Sir Edward Mellanby, F.R.S., have been eminent scientific men : its governing body is its Council which is composed for the main part of distinguished workers in medicine and the allied sciences.

It has free control of funds once allocated to it, and has never in fact been held up, for any important project, by lack of money. To it is attached the Industrial Health Research Board. The National Institute for Medical Research is maintained by the M.R.C. Most, however, of its activities are carried on throughout the country in existing university, medical and other institutions, by individuals, by special research units, or by grants.

It is in close touch with many Departments of the Government and is available to help and advise any of them

It is assisted by a large number of special committees, and most of the distinguished workers in medicine and the medical sciences in the United Kingdom are, or have been, in some way associated with its activities.

It has made very great contributions, in its 30 years of existence, to medical progress : and during both the Wars has tackled very effectively a number of emergency problems which have turned up.

Its Secretary reports directly to the Lord President of the Council.

The *Department of Scientific and Industrial Research* was founded in 1916. It is similarly placed under the Lord President of the Council ; not under the Board of Trade. Its executive head is its Secretary, who ranks with the Chief Permanent Secretaries of the main Departments of the Government. The last three Secretaries have been eminent scientific men, Sir Henry Tizard, F.R.S., Sir Frank Smith, F.R.S., and now Sir Edward Appleton, F.R.S. It has

an Advisory Council composed for the most part of distinguished scientists and engineers, with a certain number of eminent industrialists with scientific interests. The last two Chairmen of the Advisory Council have been Lord Rutherford, F.R.S., the great physicist, and Lord Riverdale (formerly Mr. Arthur Balfour) a great industrialist.

The D.S.I.R. has a very large number of activities of which only a few need be referred to. It is responsible for the National Physical Laboratory in which there are divisions of engineering, physics, electricity, aerodynamics, optics, radio, ship design, metallurgy and metrology. It maintains laboratories or establishments for

Chemical Research
Fuel Research
Road Research
Building Research
Food Research (including the Low Temperature Station at Cambridge)
Food Pests Research, etc.

It is concerned also with a large number (24) of co-operative Industrial Research Associations which are joint interests of the D.S.I.R. and the various industries : about 40 per cent. of the expenditure of these Associations comes from the Government through the D.S.I.R.

It is associated with the activities of many Departments of the Government but, is outside all of them. This greatly strengthens its position as a national agency for research. During the present war the greater part of its effort has been turned over to problems connected with the war.

It distributes maintenance grants for ' students in training for research ', particularly in such subjects as are related to industry, and it supports research under experienced investigators in any laboratory or institution in the country.

The *Agricultural Research Council* was established in 1931. It also is under the Lord President, not under the Ministry of Agriculture and Fisheries. Recently a separate Agricultural Improvement Council was established in that Ministry for applying the results of research directly to the practical problems of agriculture : the Agricultural Research Council and the Agricultural Improvement Council are independent of one another but their work is closely linked by common membership, etc. The four Secretaries hitherto of the A.R.C. have been eminent scientific men, in order, Sir William Dampier, F.R.S., Sir Edwin Butler, F.R.S., Professor W. W. C. Topley, F.R.S., and now Mr. J. C. F. Fryer. The Secretary of the A.R.C. reports directly to the Lord President of the Council.

The A.R.C. has a Field Station of its own. It also maintains or assists work going on in universities and research institutions.

It is possible that another *Research Council* may be established, also under the Lord President, to deal with all those branches of research which cannot be classified as Medical, Industrial or Agricultural (for example in ecology, marine and fresh-water fisheries, oceanography, meteorology, cytology and genetics, psychology, general physiology, biophysics). At present many of these are lacking any Government support and they do not make to the private benefactor either the sentimental appeal of medicine or the practical appeal of industry or agriculture. If this fourth Council were formed the picture of direct Government intervention in science would be complete.

The *War Cabinet Scientific Advisory Committee* was set up in 1940 under the Lord President of the Council. Originally Lord Hankey, F.R.S., was

Chairman and later Mr. R. A. Butler : both were Cabinet Ministers. The arrangement now is that the Lord President of the Council is President of the Committee, while the President of the Royal Society is Chairman in his absence. The membership of the Committee is (i) the three Secretaries of the D.S.I.R., M.R.C. and A.R.C. respectively, and (ii) the three principal officers of the Royal Society. This ensures a balance of ' official ' and ' unofficial ' science in the membership.

The chief function of the War Cabinet Scientific Advisory Committee is to discuss the more general questions of scientific policy, or any special and important matters referred to it by the Cabinet. It took an active part, for example, in plans for closer scientific liaison between Britain and the U.S.A. : it has advised on a number of special scientific appointments : it took an important part in the discussions which led to the appointment of the three Scientific Advisers to the Minister of Production : it initiated the critical consideration of the Armaments Organization of the Royal Arsenal which finally resulted in important changes in the Armaments Research Department and the Armaments Design Department : it has reported twice on service research organizations, and made proposals for future arrangements : it has produced a Cabinet paper on the use and dedication of patents : it started discussions, which have resulted in a confidential report by a Treasury Committee, on the pay and status of scientific men in the Government service : it has made plans for the preparation of a scientific history of the present war : and it has advised on a number of matters at present confidential. This list of typical examples shows that the War Cabinet Scientific Advisory Committee has found an important part to play in the ' high-level ' discussions of scientific policy, etc.

Although named the War Cabinet Scientific Advisory Committee at its foundation in 1940 it seems pretty likely that under another title and perhaps with a different constitution it will continue after the war is over. Its membership, partly official and partly unofficial, has proved satisfactory for its main purpose. Frequently, of course, it invites scientific men from outside, or representatives of the services, to be present for the discussion of special subjects, or to give evidence : and on several occasions it has had valuable meetings with scientific men and others from the Dominions or the U.S.A.

A member of the Cabinet Secretariat acts as Secretary to the Committee.

This short account describes the Central Organization for Scientific Research in Great Britain. Of course a vast amount of research is done entirely outside the Government system, (i) in universities, medical schools and other privately endowed institutions, and (ii) in industry. Moreover, a considerable part of the research done under or for the Government is not centralised under the Lord President : the most notable part of that is for the Defence Services and Home Security, but, in addition, there is research under the Colonial Office in and for the Colonies, research under the Post Office, and the work of the Government Laboratory (chiefly chemistry, in connexion with Customs and Excise), not attached to any Department : and there are various odds-and-ends of research (e.g., for fisheries) done under the auspices of a peculiar and anomalous body, the Development Commissioners. These odds-and-ends could be tidied up if a fourth Research Council were formed in the Lord President's organization (see above) : the Colonial Office work is well tied-in, by common membership, with that of the three Research Councils and the War Cabinet Scientific Advisory Committee : the work of the Post Office and the Government Laboratory is mainly *ad hoc* : and the work for the Defence Services obviously needs special treatment, though in peace-time it could with advantage be more closely associated with that of the Central Organization.

In India under the Central Government a variety of separate Departments and other bodies are responsible for research. *Meteorology* (Section 15) is under Posts and Air ; the *Geological Survey* (Section 11) is under the Labour Department ; the *Survey of India* is under Education, Health and Lands ; so are the *Zoological* and the *Botanical Surveys* (Section 11). *Medical Research* (Section 8) comes under two authorities :—

(i) the Indian Research Fund Association which is an independent registered body deriving its funds from, but not controlled by, the Department of Education, Health and Lands ; it has free use of its funds, and its method of working is rather similar to that of the Medical Research Council but on a much smaller scale :

(ii) the Department of Education, Health and Lands which, with contributions from the Provinces and States, is responsible (in some cases jointly with Provinces and States) for the Research Institutions referred to in Section 7 above : there are about 30 officers in the medical research section of the I.M.S., which is under the Department of Education, Health and Lands.

Agricultural Research (Section 10) also comes under two authorities :—

(i) the Imperial Council of Agricultural Research, which, like the Indian Research Funds Association, is an independent registered body : it derives its funds from a cess on exported agricultural products, and by adjusted contributions from the Central Government, the Provinces and the States :

(ii) the Department of Education, Health and Lands which is responsible, by adjustment with Provinces and States, for a number of Research Institutes, including the Imperial Agricultural Research Institute.

Scientific and Industrial Research.—(Section 12) as it started under the Government of India in 1940 was directly under the Department of Commerce In 1942 a change in its constitution was brought about and it was placed under a governing body called the Council of Scientific and Industrial Research, which is an independent registered body of which the Chairman is the Hon'ble Member for Industries and Civil Supplies. Recently it was decided to have the Secretary of that Department as Vice-Chairman for two years, in order to relieve the Chairman. It was further recommended that certain powers, particularly in regard to administration and finance, should be handed over to the Director of Scientific and Industrial Research. There is a Scientific Advisory body, the Board of Scientific and Industrial Research, of which also the Hon'ble Member is Chairman.

Research for the Fighting Services.—(Section 18), so far as it yet exists, is under the organization of G.H.Q.

In the Provinces and States research is widely dispersed under many separate authorities, sometimes in adjustment and consultation with authorities of the Central Government.

The Universities are maintained by the Provinces and States. There is as yet no central University Grants Committee as there is in the United Kingdom, nor is there any central fund for assisting and promoting research in them.

If scientific research in India is to make a concerted and co-ordinated contribution, as it ought, to national development in all its phases, it should be brought together under some more systematic plan. There is a special reason for this in India in the fact that so many of the institutions and laboratories at which research is being or might be done, and so many of the agencies by which the results of research are being applied to the practical problems of improving public health, prosperity and welfare, are under the Governments

of the Provinces and States. A common policy in research can only be arrived at by understanding and appreciating the needs, the resources, the weaknesses and the susceptibilities of all of them. So long as the research organization of the Central Government remains dispersed under a number of separate Departments or bodies, most of them having many other serious duties and preoccupations, there cannot be the same hope of arriving at the best common plan. If anything at all should be common to India as a whole, surely scientific research can be among the first to claim that common interest. Can that be fostered, however, by a number of different Departments of the Central Government and other bodies acting independently ?

There are six main categories of scientific work affecting the welfare of the country, in addition to the ' pure ' or academic research lying at the back of each of them. These relate respectively to :—

(1) Medicine and Public Health.

(2) Agriculture and Animal Husbandry.

(3) Industry.

(4) Surveys and Natural Resources.

(5) Engineering (particularly, but not exclusively, civil engineering, dealing with roads, aerodromes, irrigation, bridges, soil stabilisation, dams, etc.).

(6) The Defence Services.

Many subjects overlap several of these main categories. Nutrition for example lies in the fields of (1), (2), (3) and (4) : meteorology of (2), (3), (4) and (6) : metallurgy of (3), (4), (5) and (6) : fisheries of (2) and (4) : electrification, and geology and geophysics, of (2), (3), (4) and (5). Such overlap must be accepted as inevitable, indeed desirable : but its inevitability further strengthens the case for bringing all six categories of research under a single central organization.

In the United Kingdom the Lord President of the Council is a Minister of a very special kind. He has no ordinary department. From 1940 to 1943 Sir John Anderson, who held the post, took over for the Prime Minister a number of duties to which the latter's preoccupation with the war did not allow him time to attend. Lord Woolton now as Minister of Reconstruction is presumably in a somewhat similar position in relation to future planning. Recently in India an analogous appointment has been made, to the Governor General's Executive Council, of a Member for Planning and Development. This presents the possibility of placing under a single Minister without ordinary departmental duties, on the analogy of the Lord President in the United Kingdom, a *Central Organization for Scientific Research*. The actual practical steps of Development would still need to be taken by Departments of the Central Government, or of the Provinces and States : but the research would be brought together.

The Central Organization for Scientific Research working under the Hon'ble Member for Planning and Development would have the following constitution :

(A) *Six Research Boards* would be set up, the Medical Research Board, the Agricultural Research Board, the Industrial Research Board*, the Board of Surveys and Natural Resources, the Engineering Research Board, The War Research Board.

(B) Each Board would have as *Chairman* an eminent person, either a scientist or a professional men in the field concerned—a man of the type of Lord Rutherford, Lord Riverdale or Lord Hankey. The Chairman

*The words 'scientific and' should be omitted : the other Boards would be equally 'scientific'.

would not be concerned with the detailed administration of the work of their Boards. The Member for Planning and Development would not be Chairman of any of the Boards : the Chairmen would report to him.

(C) The *Members of the Boards* would be eminent and experienced scientific men, together with a certain number of professional men in the respective fields : the Boards should be primarily scientific, and the professional men should not outnumber the scientists, the purpose being research. In the appointment by the Lord President of members of the three Research Councils in the United Kingdom the concurrence of the President of the Royal Society has to be obtained in each case. Some safeguard of this kind would give confidence to Indian scientific men. Perhaps the National Institute of Sciences of India might be allowed to nominate some of the members of the Boards. There would be a certain number of *ex-officio* members representing Development interests (see below).

(D) The work of the several Boards should be co-ordinated by providing for a sufficient degree of *common membership.*

(E) In each subject there should be a *Director of Research.* He should be a scientific man of high standing. He would be *Secretary and principal administrative officer* of his own Board and a member *ex-officio* of each of the other Boards. He would be given adequate scientific and administrative assistance. He would be answerable to the Member for Planning and Development and would have the status of a Joint or Additional Secretary of an ordinary Department.

(F) The Director of Medical Research,

The Director of Agricultural Research,

The Director of Industrial Research,

The Director of Surveys and Natural Resources,

The Director of Engineering Research, and

The Director of Scientific Research in the War Department

would be responsible, with the advice of their Boards and under the Member for Planning and Development, for *directing, organizing, initiating and co-ordinating research,* on a nationwide scale so far as constitutional considerations allowed, in their respective fields.

(G) Each Board would appoint *Committees* dealing with the various aspects of its work : the Chairman of these Committees would be selected from among members of the Board and would be encouraged to take considerable initiative.

(H) *Joint Committees* would be set up between two or more Boards for dealing with special subjects.

(I) Each Board would have the power to allocate *grants for specific researches* in its own field, to be carried out by agreement in any institutions in India.

(J) A *Research Grants Committee* would be set up jointly between the different Boards, to award grants to university and other laboratories throughout India, for the encouragement of fundamental scientific research in general. If a University Grants Committee were set up, these general research grants would be given in consultation with it. (See also Section 23).

(K) A *Research Studentships Committee* would be set up jointly between the different Boards, to consider applications for Research Studentships by

young workers of proved ability desiring to gain further research experience, particularly in good laboratories abroad (see Section 3).

(L) All Chairmen and Members of Boards and Committees, apart from official and *ex-officio* members, would *retire after a period* of service to be determined. After a suitable interval they would be eligible for re-appointment on similar terms.

(M) Each Director of Research would prepare *estimates* for the work of his Board, which after discussion and approval by the Board would be submitted to the Member for Planning and Development. A *Joint Estimates Committee* under the chairmanship of the Member or his Secretary would compare and co-ordinate the different estimates, before submission to the Finance Department.

(N) After the estimates had been approved, each Board would be able freely to spend the funds at its disposal without further application or argument.

A *Scientific Consultative* Committee would be appointed to advise the Member for Planning and Development on general policy in relation to research, and on any special matters submitted to it. It would consist of the six Directors of Research together with six other distinguished scientists, one in each field : the latter should not be officials of the Central Scientific Organization, though they could be members of any of its Boards, or research workers in its institutions. The six unofficial members would retire after a period of service to be determined, but would be eligible for reappointment after a suitable interval. One of the six unofficial members would be elected as Chairman of the Committee. The Chairman would report the findings of the Committee to the Hon'ble Member.

The establishment of a National Research Council has been much discussed and strongly advocated recently by Indian scientific men, and the National Institute of Sciences of India passed formal resolutions on the subject at the beginning of this year. The opinions have been justly held : (i) that Indian science has not yet been given the opportunity of making the contribution it could make, both to the war effort and to public welfare ; (ii) that the unofficial scientists of India have had little influence or means of making their views known ; (iii) that scientific research under the Government of India is dispersed between different Departments and bodies and unco-ordinated at the top ; and (iv) that much more effort should be devoted to and money spent on research. The resolutions of the National Institute of Sciences were designed to overcome these difficulties, and to give Indian science and Indian scientific men a greater and more appropriate part in national affairs.

The present proposals are designed to meet the same needs and difficulties as the proposals of the National Institute of Sciences : they are somewhat different in form, being based on considerable experience in the United Kingdom. I believe they would be acceptable to the National Institute of Sciences.

In India unfortunately there is commonly assumed to be a fundamental antagonism between the official and the unofficial, between the individual and the Government. This idea, not unnaturally, tends to colour the views of the scientific community, and independent scientific opinion in India would probably prefer to introduce stronger safeguards than I have suggested for the claims and influence of unofficial science. It is quite true that the unofficial science of a country is the backbone of all its scientific work. Having played on both sides, however, in this game I do not believe in safeguards which are a permanent sign that one side is nervous that the other side will not play fair. If a proper organization is created, the good sense of both sides will prevail and 'official' and 'unofficial' will co-operate in working it properly.

It is realized that the setting up of the Central Organization for Scientific Research proposed above would mean considerable changes in the attachments of various existing scientific organizations and establishments to Departments of the Government : but it would not imply any substantial alterations to those organizations and establishments themselves, except in so far as such alterations were decided on later for the expansion of their work or for the more efficient conduct and co-ordination of their activities. In the main, existing organizations and establishments for research could be transferred as they are to the new set-up, though in existing circumstances the transfer might very well have to be carried out gradually.

It may be objected that the effect of removing Research from the direct control of the various Departments under which it now is would be damaging to the other work of those Departments. That might seem indeed to be the immediate effect, and obviously a temporary disturbance would be caused. The final result, however, would be that more and better research would be done, that the various branches of research would be brought into better co-ordination with one another, that gaps and weaknesses now apparent would be made good, and that a more uniform and consistent effort would be devoted to the whole business.

It is mistake in general to tie up research too directly to the solution of immediate practical problems : and those who were responsible in the Departments for tackling the practical problems would be able, by *ex-officio* membership of the various Boards and Committees, or by contact with the various Directors of Research, to obtain all the scientific information they required and to give sufficient bias to the directions in which research was undertaken.

Nobody in the United Kingdom would now suggest putting the National Institute for Medical Research under the Ministry of Health ; the National Physical Laboratory or the Industrial Research Associations under the Board of Trade ; the Industrial Health Research Board under the Ministry of Labour ; the Geological Survey under the Ministry of Labour or the Ministry of Fuel and Power ; the Food Investigation Board and its laboratories under the Ministry of Food ; the Radio Research Board and its establishments under the Post Office ; the Building Research Station under the Ministry of Works : while any suggestion of putting the Agricultural Research Council and its Field Station under the Ministry of Agriculture and Fisheries was obviated, and a much better solution arrived at, by setting up an Agricultural Improvement Council in that Ministry. It is difficult to see why the same general principle of bringing Research into a single organization, and of leaving the Departments to make their own arrangements for applying the results of research to the practical problems they have to face, should not apply to India also.

One great objection to the organization of research under a number of separate authorities, quite apart from the lack of co-ordination and a common plan resulting from it, is that financial and other support for research is often patchy and inadequate. The present sorry position of the Zoological and the Botanical Surveys of India, and of Fishery Research, is a good example of how important scientific activities can be starved under a Department in which, at some moment, there was a failure of interest in them. The decision not to complete the 1941 Census of India could never have been taken if its consequences had been properly thought out. Even from a Department in which there is plenty of interest, financial support may be quite inadequate : the Indian Research Fund Association, for example, does excellent work on the same lines as the Medical Research Council in the United Kingdom, but it could spend with advantage many times the present amount, e.g., in establishing Clinical Research Units in medical colleges. Under a central organization for research the different subjects could hope to be treated with some degree of

uniform encouragement, according to their needs. There is possible danger, for example, in India of Industrial Research, under capitalist pressure, being regarded as the main or only interest, to the partial exclusion of others. Such a possibility could be obviated by bringing all forms of research into a single system, in which all interests would be considered together and a uniform healthy development planned.

If these proposals for a central scientific organization were adopted it would be well to set up, in the ' user ' Departments, *Development or Improvement Councils* (similar to the Agricultural Improvement Council in the Ministry of Agriculture) to apply the results of research directly to the various practical problems affected by it. Joint *ex-officio* membership either way of an Improvement Council and its corresponding Research Board (or Boards) would ensure on the one hand that the results of research were fully known to those who had to apply it, and on the other those who had to do the research were kept aware of the practical needs.

It may seem to some that the distinction between Research on the one side and Development (or Improvement) on the other is arbitrary and unnecessary : but in fact it is better to be quite clear about the sequence of processes by which pure research at the one end is translated into large scale production or application at the other. In engineering we hear about research, technical development and large scale industrial production. It is true that the exact boundary between these is sometimes blurred, but so is that between many processes which in principle are distinct : to suppose that they are all fundamentally the same, that they can best be carried out by the same people in the same laboratories, workshops or factories, may very well result in difficulties being glossed over or essential stages omitted. The same fundamental distinctions exist in other activities than engineering, e.g., in medicine and public health, or in agriculture. First, there is the original scientific inquiry, followed by early laboratory attempts to see if the outcome of the inquiry is likely to yield practical results of importance. Second, there is the development process, the pilot-plant stage by which the practical results are produced or tested experimentally on a small scale, in the workshop or the field. Third, there is the final stage, carried out on the large scale required for industrial production or national application.

If then a Central Organization for Scientific Research of the kind here proposed were set up, the various Departments of the Government would still be left to deal with the second and third stages, corresponding respectively to Development and Production. I do not believe that in the long run any damage would be done, but rather the reverse, to the work of Departments by embodying in the organization a fundamental distinction which does in fact exist, even though it may be obscured in the by-no-means perfect system at present existing.

In order to ensure that Development as well as Research is well looked after and co-ordinated at a high level it would probably be wise to set up, under the Member for National Planning and Development, as an opposite number to the Scientific Consultative Committee, a *Development Consultative Council*. This also would have a few appointed independent members from industry or the professions concerned ; other members *ex-officio* would be the Secretaries of the interested Departments, together with the executive and technical officers responsible for the relevant Development Sections or Improvement Councils. This would imply no interference with the executive responsibility of Departments to deal with their separate projects of Development : it would only ensure that attention was kept focussed on those various projects, that the Member for Planning and Development was kept properly informed of them, and that they were welded together into a consistent and well balanced national plan.

(20) A CENTRAL REGISTER OF SCIENTIFIC AND TECHNICAL PERSONNEL.

At the end of 1938 in the United Kingdom the Central Register of the Ministry of Labour was established. Its purpose was, in case of war, to provide a national register of all people with higher scientific, technical or professional qualifications who would be available for posts in government work or in essential industrial or other service.

The Scientific Section of the Central Register was constructed by the Royal Society in collaboration with various national scientific societies or institutes. The Technical Sections were compiled by the Engineering and other Institutions. A Medical Register was constructed separately by the British Medical Association. The Central Register has been worked by the Ministry of Labour and National Service, under an experienced Director and expert scientific assistants, with the advice, when required, of expert panels in the various subjects. It is as nearly complete as any such register can be. For some years it has been the main channel by which scientific and technical personnel have been selected and made available for work connected with the national war effort.

In certain categories, e.g., of physicists and engineers, a shortage began to appear quite early in the war. Under the direction of Lord Hankey the Central Register undertook the selection and training of suitable young people. Very large numbers have been made available in this way.

In the United States in 1940 a similar National Roster was set up. It has functioned in much the some way as the Central Register.

The Central Register has been an essential part of the scientific and technical effort made in the United Kingdom. It is regarded now as an institution of permanent value to the country, to be kept in being and up-to-date after the war. Exactly how it will be organized and used in peace-time has not been decided.

In India partial registers have been constructed for special purposes, but none which is general and authoritative, or dealing with people in all subjects of science and technology. It is not a simple matter to construct or use a really effective register : it cannot be left to clerks, but requires expert and critical handling. The value to India of a Central Register of Scientific and Technical Personnel, critically constructed and handled by experts, would probably be great, not only in meeting the scientific and technical needs of the war as these continue to emerge, but also in the great process of national development, involving science and technology in almost all branches, to be foreseen after the war. In a survey of national resources, a critical assessment of the scientific knowledge, skill and experience available must be reckoned one of the more important items.

The construction of an Indian Central Register for Scientific and Technical Personnel would not be expensive, but it would require a good deal of expert guidance and help. I did in fact suggest to the Officers of the National Institute of Sciences of India that the National Institute itself should undertake its construction, and I understand that a beginning has been made. Its administration and use would have to be taken over finally by some central scientific agency of the Government of India, e.g., by the Central Organization for Scientific Research referred to in Section 19. The experience of the Central Register in the United Kingdom would be made available to India

(21) THE PAY AND STATUS OF SCIENTIFIC WORKERS IN THE GOVERNMENT SERVICE.

Some concern has been expressed in the United Kingdom in recent years about the position of scientific men in the Government service. As regards pay, the administrator has been paid 50 per cent. more than the scientific or technical man of the same standing, experience, training and ability : and the scientist, however able and productive, has been unable to attain more than a very limited position and salary without taking on administrative work, often to the exclusion of most else.

Moreover in many scientific jobs under the Government the conditions and amenities of working, facilities for publication and discussion, possibilities of attendance at scientific meetings and conferences and recognition by colleagues of one's scientific work, are all less attractive than they need be. The consequence has been that teachers have tended to deflect their ablest pupils from scientific service under the Government.

Substantial improvements are likely to result from recent discussions in the Treasury, and from a realization that it is false economy not to offer at least as attractive conditions in the Government scientific service as exist outside it. I realize that the position is not the same in India as in the United Kingdom, and other factors are involved : for example, conditions of service in the universities and in industry are not nearly so attractive in India as in Britain. Undoubtedly, however, scientific service under the Government is not in general comparable in pay and status with the civil service or such as to secure the appointment of the ablest men, or to give them the best opportunities for developing and utilizing their talents. In the next few years there will need to be a great increase in the number of scientific men employed in the service of the Government of India : it will be very desirable to make the conditions of their employment such as to attract and hold a substantial number of the best men, and to give all of them as good opportunities as possible for their work and its recognition by their colleagues outside.

In view of this it might be wise to set up in India soon a small Committee to consider the whole subject. The Indian scientific men who are coming to London in October could ascertain what improvements are likely to be effected here : this knowledge might be of value to them as a general guide in the discussions which would take place later in India.

(22) SCIENTIFIC SOCIETIES IN INDIA.

The development of science in every country depends very much on the familiar association of scientific men in the activities of scientific societies. These are the common meeting grounds at which ideas are ventilated and criticised, new facts discussed, common policy decided and people get to know each other. The progress of science in the United Kingdom has been intimately bound up with the development of its many learned societies, starting with the Royal Society in 1662.

We are fortunate in Great Britain in having in the colleges of the older universities, in some of the senior common rooms of the newer ones, in various clubs and in many other such associations, a means of bringing scientific men and scholars into close and familiar contact with one another. There are fewer opportunities for such contacts in India. It is all the more important therefore that scientific societies should be fostered and encouraged.

Scientific societies are of two kinds, general and special, with memberships drawn respectively from the whole of science or from a single branch of it.

Both kinds have an important part to play in the publication of scientific papers and results, and—through their libraries and collections—in providing repositories of scientific information. Scarcely less important is their influence in making living communites out of a number of people always ertical and often highly individualistic. In India where so many causes tend at present to separate individuals, groups and communities from one another a strong common interest in science as a whole, or in some branch of it, could have as a bye-product an important influence in keeping people working sensibly together.

The oldest learned society in India is the Royal Asiatic Society of Bengal, originally the Asiatick Society, which was founded by Sir William Jones in Calcutta in 1784. From its activities has sprung by far the larger part of subsequent scientific activity in India, not to mention all its own work for literature, history, archæology and philology. It may be regarded as the mother of the Indian Science Congress Association which held its first meeting in 1914, and the grandmother of the National Institute of Sciences of India established in 1935. The Indian Science Congress Association has taken already a great place in Indian scientific activity : it is the opposite number of the British Association for the Advancement of Science. Besides the National Institute of Science, which is the nearest equivalent in India of the Royal Society, there are two other general scientific Academies claiming national scope :

(a) the United Provinces Academy of Sciences founded in 1930 at Allahabad, which was intended primarily to cater for all branches of science in Northern India ; it was renamed the National Academy of Sciences, India, in 1936 ; and

(b) the Indian Academy of Science founded at Bangalore in 1934.

Of these three, the body best suited by constitution and membership to assume the role of a national academy of science, such as,

The Royal Society (London),

The National Academy of Science (Washington),

The Royal Swedish Academy of Science (Stockholm),

The Royal Danish Academy of Science (Copenhagen),

The Academy of Science of the U. S. S. R. (Moscow), etc.,

is the National Institute of Sciences of India. It is oddly named for such a body but that was due to a compromise which was necessary at the time it was founded. Its present headquarters are in the rooms of the Royal Asiatic Society of Bengal in Calcutta, but it has decided, when possible, to transfer its headquarters to Delhi. It hopes, as time goes on, to take over in India more and more of the functions which are discharged by national academies of science in other countries.

The National Institute of Sciences was invited last winter by the Royal Society to send representatives to London for the discussion of such matters and to concert joint plans for the co-operation of the scientific societies of India and of the United Kingdom. Among plans to be discussed will be those for the Imperial Scientific Conference to be held soon after the war is over, possibly in the summer of 1945. The time is coming when India will be an independent unit of the British Commonwealth : with science as important as it will be in the world of tomorrow it will be essential for Indian science as a whole to have some strong independent national scientific body to represent it both to the Government of India and in relation to the science of the rest of the world. It is hoped, therefore, by the National Institute of Sciences that some formal recognition may be given to its position by the Government, for example by a Royal Charter such as the Royal Society and the British Academy have. Few

things could do more to stabilise the position of science in India, or its relations with science in the rest of the Commonwealth, than to have a strong and effective national academy of science, independent of the Government but recognised by the Government.

There are now specialist national societies in India in most scientific subjects, e.g., in Geology (1906), Mathematics (1907), Botany (1921), Chemistry (1924), Physics (1934), Soil Science (1934), and Physiology (1934). Some of these are of nation-wide membership and scope, others have as yet only a small membership and influence. Most of them were started by the initiative of scientists in Calcutta, and some have not yet been properly supported in other parts of India. It is not yet sufficiently appreciated that the status of a scientific subject depends to a considerable degree on the strength of its corresponding society ; if, for example, physiologists throughout India complain of the little regard paid to their subject, they should join and support, and take joint action through, the Indian Physiological Society.

All these scientific societies are a product of the independent activities and keenness of scientists themselves. They cannot be a direct concern of the Government. The Government, however, could assist and encourage them in various ways which would not diminish their independence. For example :

(a) they could be invited to appoint representatives on government advisory committees or boards ;

(b) they could be invited to institute special inquiries, to collect information, or to advise, on matters of national importance ;

(c) grants could be made to assist their scientific publications ; these could be allotted by the National Institute of Sciences as corresponding grants in the United Kingdom are by the Royal Society ;

(d) a Government Grant-in-aid for Scientific Investigation, and another for International Scientific Conferences, could be put at the disposal of the National Institute of Science for distribution, as is done by H. M. Government in the United Kingdom to the Royal Society ;

(e) universities and other employers could be advised that attendance, within reasonable limits, at meetings of scientific societies may be regarded as among the normal duties of scientific men ;

(f) financial assistance could be given to their libraries and museums, and towards the expenses of delegates to meetings in India or abroad.

In this connexion, a proposal has been made by Sir Henry Tizard that, in lieu of government subsidies to air lines, the Government might purchase a certain mileage of air travel and allot it for distribution to such bodies as scientific societies. This would certainly help to ' mix scientists up '.

The expenditure involved in such grants or assistance would be small, but would produce an effect altogether out of proportion to its extent. It would be natural for the National Institute of Sciences to take up such matters with the Government, on behalf of its sister societies.

(23) SCIENTIFIC RESEARCH IN INDIAN UNIVERSITIES.

This subject would require long and careful study and much fuller consideration than I have had time to give it. It might be wise at a later stage to appoint a small Commission, under an able and experienced scientific man as Chairman, to go into the whole subject. All I can do now is to make a few general comments.

(A) Scientific research in the universities, both for its own sake and as a background for scientific education, is *the fundamental basis* of all scientific progress.

(B) Research in the *pre-clinical sciences* and in *clinical medicine* has been referred to in Sections 6, 7 and 8. So far as it exists, it is mainly conducted in medical colleges which, although formally attached to universities, are largely independent of them. In the United Kingdom the tendency now is to bring medical education and research more and more under the influence of the universities (see the Goodenough Committee's report)) : of the wisdom of this in Great Britain I have no doubt whatever. It may be that in India there are special difficulties which make this undesirable : if so, that is a very unfavourable comment on the universities themselves and points to conditions which ought to be put right. It could equally well be argued that the present unsatisfactory state of research in the medical colleges is due to the absence of academic influence or a university atmosphere. The subject deserves full and careful consideration. The present state of affairs ought not to be allowed to continue without full examination.

(C) The most notable contributions of Indian scientists have been in *physics, mathematics and chemistry*. It cannot be expected that strong departments in all scientific subjects should exist at all centres, but there are in fact a good many strong departments in physics and chemistry in Indian universities. No doubt the situation in these subjects could be greatly improved still, but the tendency to do so already exists and must be encouraged.

(D) In the *biological sciences*, the university departments are nearly always small, ill-equipped and under-staffed. The modern physiological or functional approach to zoology, which has been the chief feature of the subject in the United Kingdom and the United States for a good many years now, is almost completely absent. There is very little original work of any kind going on in cytology or genetics, in spite of the great practical interest of the latter in an agricultural country. Biophysics is almost completely absent, except at the Bose Institute in Calcutta which is not a department of the University. Biochemistry is quite strong in some centres, but tends to be associated with chemistry rather than physiology, zoology or botany. Except in one or two centres physiology has no place outside the Medical Colleges, in spite of its importance for general education.

There is a growing conviction in Great Britain, the United States and (I believe) the U. S. S. R., that many of the future great applications of science will be in the biological field ; or perhaps rather in the field intermediate between the biological science on the one side and the physical (including chemical) sciences on the other. For these applications, which are already becoming apparent in various directions, India will be ill prepared unless the biological departments in the universities are greatly strengthened.

(E) In *geology*, so far as I have been able to gather, the universities are weak. If geological work is to be pushed on in India, as national development demands, a certain number of good university departments of geology will be required.

(F) I have seen too few *Engineering Colleges* to be able to make any very useful comments. The Engineering College at Madras (founded in 1794) seemed to me an excellent institution, well supported by the Madras Government : its Principal had no complaint except of the urgent need, as he felt it, to send the younger member of his staff for further technical experience and training in research to the United Kingdom (see Section 3). There are some good engineering laboratories at the Bangalore Institute.

In Section 14 above I have suggested that there ought to be founded in India a few Colleges of Technology on a really great scale, like the M. I. T. at Cambridge, Mass. That, however, would not obviate the need for the various universities to maintain departments in engineering and technology of a sufficient standard to meet the ordinary needs of industry and public works for men well trained and accustomed to the idea of research. I have no evidence as to whether the majority of the existing engineering colleges and departments are of that standard : but knowing the very high requirements of modern engineering laboratories, and the heavy cost of their equipment, I should doubt it.

(G) It was suggested above, Section 19, I, J & K, that grants for special researches, for research work in general and for research studentships, should be distributed on a national scale by the proposed Research Boards and Joint Committees of them. If the funds put at the disposal of the Boards for the purpose were large enough this would have a most beneficial effect on research in the universities. If a University Grants Committee were established the Joint Research Grants Committee should work in close consultation with it.

In allocating general research grants from central funds to a university, or university department, it might usually be made a condition that some proportionate grant should be made by the local authority concerned. This is a common practice with the Rockefeller Foundation and other benefactors, and it has a good effect in exciting a local interest and pride in the object of the benefaction. If an interest in scientific research is to be raised and maintained in India as a whole, the establishment of a central grant-giving body with substantial funds and a carefully thought out national policy would probably be the best way to set about it.

The Royal Society last winter set up a number of special committees to investigate the post-war needs of fundamental research in the United Kingdom in various fields. These committees have now reported and representations will be made by the Society to the appropriate authorities. Nearly all the recommendations affect the conditions of research in the universities. Other reports affecting scientific research in the universities have been published in the United Kingdom during the last year, e g., by the Association of Scientific Workers, the Association of University Teachers, Nuffield College, the Parliamentary and Scientific Committee, etc. Similar investigations under independent auspices, conducted for example by the National Institute of Sciences, or the Indian Science Congress Association, would be valuable in India.

(24) PRIVATE BENEFACTIONS TO SCIENCE.

Substantial benefactions have been made to science, medicine and technology in India from private sources, particularly by the Tatas. Most, however, of the scientific work done in India derives its financial support from the Government. Government support usually means more or less of Government control, and although that need not be the bogy it is often represented to be there is no doubt that a reasonable measure of independence is desirable in any organization for research : indeed of fundamental scientific work done in the past in other countries the vast majority has been carried out in independent institutions. Scientific research in Government establishments may be very good indeed, but it can rapidly become dull or sterile, particularly in normal times, unless it is continuously fertilised by contact with imaginative thought from outside, or prodded by independent criticism. Until human nature changes it will continue to be a great safeguard that scientific research should not be solely dependent on Government support, but should have independent resources and an independent existence.

Although India on the average is a poor country there are rich men in it who, if they were so minded, could without feeling any significant difference themselves, contribute enough to the promotion of scientific research in India to produce a very substantial improvement. One of the greatest needs in India is of scholarships, studentships and fellowships for research. Nearly every outstanding British scientist has at some time or other benefitted from these : their number is great : Indian scientists could benefit at least as much were they available in India. That is an obvious direction in which private benefactions could be applied without any danger—which does in fact exist—that a private gift may merely cause a reduction in a Government grant. In Great Britain we have Beit Fellowships, Leverhulme Studentships together with the scholarships, studentships, fellowships, etc., of the universities, the Royal Society, the 1851 Exhibition, and many others of the same kind for scientific or medical research. As a recent industrial example, Imperial Chemical Industries announced this summer their intention to provide 80 senior fellowships in certain British universities, averaging £600 a year in value, for research in physics, chemistry, biochemistry and some allied fields. In America there are similar benefactions associated with such names as Rockefeller, Guggenheim, Harkness, Carnegie, G. F. Baker, and very many more. What a notable contribution might be made to Indian Science if wealthy Indians could be induced to perpetuate their names by the foundation of scholarships, studentships, fellowships and research professorships, for the improvement of scientific and medical knowledge.

There are very few completely non-official scientific institutions in India. The existence of independent endowed research institutions of sufficient status can provide a very valuable stimulus and addition to science, as is shown by the contributions of the Rockefeller Institute in New York, the Royal Institution and the Lister Institute in London, and many other similar foundations throughout the British Commonwealth and the U. S. A. In India there are a few such institutions, e.g., the Indian Association for the Cultivation of Science and the Bose Institute in Calcutta, and the Tata Memorial (Cancer) Hospital in Bombay. Here again is a great opportunity for Indian benefactors.

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SCIENTIFIC EDUCATION AND RESEARCH IN RELATION TO NATIONAL WELFARE

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI.
PRINTED BY THE MANAGER, GOVERNMENT OF INDIA PRESS, NEW DELHI.
1944

Price Re. 1 or 1s. 6d.

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PREFACE

SCIENTIFIC EDUCATION AND RESEARCH IN RELATION TO NATIONAL WELFARE

Recently in the United Kingdom as elsewhere, the part which scientific and technical education and research can play, indeed must play, in all future plans of national welfare and development has been much more fully realised than before. This is partly due to the war, and for three reasons:—

(a) In many directions scientific knowledge and research have made essential contributions to warlike operations, to the production of new weapons and devices of war, to nutrition and to health:

(b) During the war Britain will have used up most of her savings and much of her material resources. Her chief remaining asset in the industrial field will be the native ability of her scientists and engineers and the skill and intelligence of her workers, particularly her young workers:

(c) In the reconstruction of the world at large, particularly of the European countries at present occupied by Germany, the gravest problems will have to be faced for years to come, many of which as in agriculture, food, health, natural resources, power, transport, etc., will require first class scientific and technical knowledge and their resolute application for their solution.

There are other reasons also not directly connected with the war, though the war may have hastened their realisation; for example:

(a) In connection with colonial development there is a growing conviction that our primary object must be not the exploitation of the natural resources of the colonial territories but the welfare and betterment of the colonial people themselves. This requires widespread application of scientific methods to colonial problems, for example, to health, population, agriculture, fisheries, new industries, raw materials, geological and other surveys, education, etc.

(b) The great and successful developments of science and technology in other countries, particularly in the U. S. A. and the U. S. S. R., have been particularly obvious in recent years and have given much food for thought not only to scientists but to ordinary men:

(c) The change over in Great Britain from the older staple industries to the newer ones, the need for conserving natural resources like coal, the common desire—as evidenced for example by the enthusiasm for the Beveridge Report—for better social, industrial and agricultural conditions and for improving the security and amenities of life, all demand the use of new methods which science and technology alone appear to be able to offer.

For all such reasons in the last few years a number of committees and other bodies have been set up, or have formed themselves, to consider the place of scientific research and technical education in relation to national welfare in its many aspects, and a number of interesting and important reports and articles have been published. These have attracted a great deal of attention in the United Kingdom, and since their findings are applicable, *mutatis mutandis*, in many ways to conditions in India it was decided to reprint certain of them in India in the present form. The collection is typical rather than complete, and in fact several more might have been added. Moreover there are others still to appear (such as the Report of the Inter-Departmental Committee on Medical Schools) and some which at present are confidential (*e.g.*, on Science in the Civil Service) all of which might have their bearing on Indian conditions and needs. It was thought best, however, to issue quickly a few of those at present available in order to show the way in which the wind is blowing in the U. K. If these are found to be of sufficient interest it will be easy for the Government of India and for Indian Science and Industry to get much fuller information as to the plans, ideas, discussions and conclusions which are now emerging in the U. K. and in other parts of the Empire. Indeed in the first of the reports reprinted below (The British Commonwealth Science Committee of the Royal Society) it is recommended:—

"That a suggestion be made to the governments of the various English-speaking countries that they should consider the possibility of maintaining permanent scientific and technical representation in London and possibly also in other capital cities of the English-speaking world:" and

"That if scientific and technical representatives of the Dominions and India are permanently established in London, these, together with official representatives of science in the United Kingdom and the Colonies, should be constituted a British Commonwealth Scientific Collaboration Committee, to act with the Royal Society in the discussion of topics of common interest, to keep in touch with all agencies and organizations for the collection and dissemination of scientific information, to further schemes for co-operation in research, and to make such recommendations and proposals for common action as seem fit."

If that plan could be carried out, very great advantage might result not only to India but to all the other countries concerned. Two-way traffic between all important points in the scientific system is essential.

The object in mind in setting up the British Commonwealth Science Committee in 1941 under the Chairmanship of the President of the Royal Society was described as follows:—

"The scientific problems provided by the war in connexion with technical devices and weapons, supply, medicine, public health, agriculture, food communications, etc., have brought scientists from all parts of the British Commonwealth into close co-operation. The efficient organization of this work had necessitated the presence in London of scientific representatives of the various Dominions, and the opportunity was taken by the Officers of the Royal Society of instituting an informal meeting ground for the consideration of joint problems. The general objectives were to secure scientific co-operation in tackling the emergency problems of the immediate post-war period and to ensure that the most should be made of our common scientific resources after the war for improving both scientific knowledge itself and the life of the peoples of the Empire."

Unfortunately there were not then, nor indeed are there even yet, any representatives of Indian science available in London to attend the meetings of the Committee, though it is hoped that this defect may soon be put right. The Educational Adviser, however, of the High Commissioner for India (Dr. T. Quayle) attended all the meetings and gave much valuable information about Indian scientific organisations.

The object in mind was, in the first instance, to plan co-operation in scientific research within the Empire, the Dominions, India and the Colonies. This, however, was regarded only as a first step towards a more general collaboration, and referring to international organisations the Committee stated:—

"Before the war there were also world organizations, such as the International Institute of Agriculture (Rome) and the World Power Conference (Paris), making valuable statistical or technical compilations and investigations in regard to agriculture and the fuel industries respectively throughout the world, and providing centres of information thereon. There would appear to be room for an international body to perform similar service in relation to the world's mineral resources."

"Most of the essential services mentioned above will need to be reviewed and revived in the most suitable form and on as widely international a basis as possible, after the war. Anglo-American initiative may be required to re-establish such co-operation. Machinery for close collaboration in research and the establishment of laboratories and institutes common to the Empire or the world, will require further consideration."

The report laid particular emphasis on the value of Common Bureaux of information such as the Imperial Agricultural Bureau, an admirable organisation of which the Director is Sir David Chadwick, who himself has wide knowledge of Indian conditions, and the present Chairman is Mr. S. Lall, the Deputy High Commissioner for India in London. A recent report by a Committee of which Lord Hankey was Chairman (not reprinted here) referred in detail to the working of these Bureaux.

The report of the B. C. S. C. emphasized the very great value of frequent and easy personal contacts and exchanges between research workers from various countries and to the facilities which air transport will provide in the future for such interchanges. Air transport is one of the practical results of science

and may in the future, in return, be widely used to facilitate those personal contacts between scientific people for which the writing of reports, papers and minutes is a very slow and inefficient substitute. Moreover the use of microfilms carried by air may greatly speed up the interchange of information between different parts of the world and may even make possible simultaneous publication of abstracting and similar journals in widely distant countries.

The second report of the present collection is one of the Parliamentary and Scientific Committee on "Scientific Research and the Universities in Post War Britain". This interesting body is an unofficial group consisting of a large number of members of both Houses of the British Parliament together with representatives of various scientific and technical societies and institutions. It has no official authority but it may have a considerable influence. It meets in a Committee Room in the House of Commons. Its President now is Lord Samuel, its Chairman Mr. E. W. Salt, M.P. Through it, Members of Parliament are able to inform themselves of current interests, trends, developments and needs in science and technology and so, if necessary, to take action with Ministers privately or on the floor of the House. It has been in existence only for a few years but seems likely in the future to grow in influence and to produce important results. It might very well be copied elsewhere. It discusses matters of general scientific interest, usually in relation to such practical matters as industry, health, colonial development, the status and pay of scientific workers, etc., but it is also concerned with maintaining scientific research and education in the Universities at a proper level. It appoints sub-committees to go into specific questions and draw up reports. Two of these reports were recently published, one reprinted here on Research and the Universities the other on the Utilisation of Coal. Both of these have evoked widespread interest in the press and elsewhere.

The Report of the Parliamentary and Scientific Committee on Scientific Research and the Universities referred to two main topics: (1) the need for increased research, pure and applied, (2) the supply and training of research personnel. There is a widespread desire in Great Britain for greater social security and a higher standard of living. The report states:—

"The resources upon which we depend for our schemes of reconstruction and social betterment will have to be used and developed with the maximum vision, intelligence and enterprise. This can only be ensured by the application of active and well-directed technological research firmly based on the foundation of scientific discovery."

"Britain cannot afford to fall behind other nations in this essential task of research, if only because of its density of population, and its position as the centre of a wide empire. If we are to maintain our position we must take full advantage of the native ability of our scientists and engineers, and the intelligence and craftsmanship of our workers. Our industry will have to concentrate increasingly on the manufacture of products which demand a special degree of intelligence and technical skill in the making. Science will have to be applied increasingly to ensure the best use and maximum yield of our soil, animals, forests, fisheries and mines, and the development of our colonies and protectorates, as well as the maintenance of health and the prevention and cure of disease."

Its conclusion is:—

"It is now recognised that in the post-war period in Great Britain research and its application must be on a far bolder and more imaginative scale than in the period 1919—1939. We ought, in fact, to look forward to spending at least 10 times as much annually after the war on research and development in order to provide the necessary basis without which neither our agriculture nor industry can meet the needs of the future."

As regards the supply of men and women of sufficient native talent and adequately trained to carry out this great task it makes a number of recommendations of which the following are important:—

(a) Expansion of the Universities and Technical Colleges and an all-round improvement in the teaching of science and scientific principles at all stages of education for the whole school population of the country:

(b) Effective organization for the demobilisation of the scientific people now on war work or in the Services:

(c) State bursaries for scientific and engineering students to enable the net to be drawn wider so as to catch the requisite natural talent:

(d) A capital grant to the Universities of the U. K. of £10,000,000, to be spread over the first five post-war years:

(e) The annual treasury grant to the Universities to be increased from £2¼ million to £6 or £7 million per annum:

(f) Part-time courses in science and technology for promising young people already employed in industry:

(g) An improvement in the status, pay and training of laboratory technicians.

As a consequence of this report a large number of Members of Parliament have put their names to the following motion which is now on the Order Paper of the House of Commons. It shows indeed the way the wind is blowing!

"That this House, recognising that if the United Kingdom is to maintain its position in the post-war world and carry out effective plans for physical reconstruction and social betterment, research and the application of scientific knowledge in all fields must be promoted on a far bolder scale than in the period 1919—1939, urges H. M. Government forthwith:—

(i) to assure the universities that in planning future developments for research, teaching and higher learning as a whole they will receive support from the State on a much larger scale than hitherto:

(ii) to arrange that education and training in schools, technical colleges and universities shall be directed at the earliest date towards providing a far greater number of persons highly trained in science and technology:

(iii) to set in motion schemes to ensure a substantial and co-ordinated expansion of research activity by private firms, co-operative industrial research associations, and State and other research establishments; and to this end, to provide assistance by adjustment of taxation, by more generous financial grants and through adequate priorities both in demobilisation and for materials required for building and equipment."

The third report reprinted here refers to Industry and Education. A private conference held at Oxford in September 1942 under the auspices of Nuffield College reached certain broad conclusions which were later embodied in the present report. Its signatories are not for the main part scientific men though there are some distinguished scientists and engineers among them. A further conference is to be held in 1944 on Scientific and Industrial Research.

The report refers among many other matters to the common illusion that the black-coated worker is somehow and for some peculiar reason superior to the skilled craftsman.

"The bias of the educational system has been recently to a growing extent against entry to manual occupations, and in favour of directing the boys who are above the average intelligence into non-manual work. We protest against this, except where the non-manual occupations are such as to call for a high degree of intelligence; but to the extent to which it is the result of a supposed prestige of non-manual work, even of a relative unskilled kind, we believe the results to be most unfortunate. It is of the greatest importance to raise the prestige of high manual skill, and to persuade boys, parents, and schoolmasters alike that the skilled crafts offer at least as promising and interesting a prospect, and as good an opportunity of advancement, as many "white-collar" jobs. Unless those who hold the key positions can be convinced of this truth, and persuaded to act upon it, the development of industry is bound to be seriously prejudiced and productivity to remain at

too low a level to satisfy the reasonable aspirations of the main body of the people."

To paraphrase a wise remark in the Stockdale Report on the West Indies, it is no service to the young people or their country to increase the number of unemployed middle-class. That is exactly what we have been doing by exalting clerical jobs at the expense of technical ones. A friend of mine, Prof. T. H. Pear of Manchester, once wrote a book on "The intellectual respectability of muscular skill". The title itself is a sermon and I imagine that the need it refers to is not unknown in India! If only our rulers, our administrators, our officials had been brought up with less knowledge perhaps of Latin, Greek, Ancient Philosophy and the Law but with greater knowledge of agriculture, craftsmanship, industry and health and of the real world in which we all have to live, if only the teachers in our schools had had a wider experience of that real practical world, how much happier we, they and their pupils might all be! Perhaps the young men and women who are now seeing the wider world in the Forces will have had enough of that practical experience to make them the better guides when they return to teaching.

The last paragraph of the report deserves repetition:

"That men work better and live more happily when they work and live in hope, and that no small part of the difficulties of industry in recent years have come from the lack of this hope, which has been spread widely by the presence and the pervasive fear of unemployment. That industry will be fruitful in proportion as those engaged in it regard themselves as the servitors of spiritual and not of merely material values, and that the presence of this spirit depends largely on removing from men's minds the spectre of unemployment and in making plain that no vested interest is to be allowed to stand in the way of the fullest possible production, or of the use of full production for the single purpose of improving the quality of human life."

If that makes one a socialist, then most of us are socialists today; but there are many members in fact of all political parties, or of none, who will agree to its sentiments. It shows again which way the wind is blowing in England!

The fourth pamphlet (Relationship of Research Associations to the Department of Scientific and Industrial Research) was addressed to the British Coal Utilisation Research Association by Mr. A. L. Hetherington, for many years the member of the staff of the D. S. I. R. whose special task it was to look after the affairs of the Research Associations. It describes the activities of those associations. These were started (as Sir Harold Hartley describes in the fifth paper)

"at the end of the last war with the help of a million pound fund voted by the Government to the Department of Scientific and Industrial Research. There are now twenty-four of them, and they are self-governing bodies, supported voluntarily by firms engaged in the industries for which they cater, or in a few cases by a levy on the raw materials of the industry in question. The Department of Scientific and Industrial Research supports the associations financially by means of annual grants to an amount depending on the subscriptions from industry. This year the total incomes of the associations will be over £800,000, of which £275,000 will be Government grant. The subscriptions vary with the size of the member firm, being in some cases as low as £10 annually for the smallest unit. Most of the associations possess their own laboratories, but some of their work is done in Government or University laboratories or in the laboratories of member firms. The control of the associations is in the hands of councils elected by the members; the results of the work are confidential to members in the first instance, but, in fact, much of it is subsequently published and added to the general fund of knowledge."

The list of the associations will be found at the end of Sir Harold Hartley's paper. It is an impressive series.

Mr. Hetherington refers to the status of these associations as a joint co-operative enterprise between private business on the one side and a Government

agency on the other. His paper deals with general policy, grants-in-aid, control of expenditure, ownership and availability of results, extra-mural investigation, points which inevitably arise in such joint responsibility. It ends by referring specifically to the co-operation of the British Coal Utilisation Research Association with the Fuel Research Station of the D. S. I. R., and to a proposal for the co-operation of various Research Associations with the Building Research Station of the D. S. I. R. This article will be of interest to those who think of starting similar Research Associations in India.

The fifth pamphlet in the collection (Are you Research-Minded? Industrial Research. What it means to British Industry) is one written by Sir Harold Hartley, F. R. S., Chairman of the Fuel Research Board, Vice-President and Director of Scientific Research of the London Midland and Scottish Railway, a prominent English chemist. The gospel he has to preach is "Make your industrial friends research-minded"—if there is a Research Association in your trade join it now, if there is none get one formed by the trade association; if there is no trade association ask the advice of the Federation of British Industries; if you have no research staff apply to the Research Association, if one exists, or to the F. B. I.; if you are in a large way of business establish a research laboratory of your own or with associate or kindred firms, as well as join the Research Association of your trade.

"What research has meant in peace-time can be seen from the savings that have come from a few inventions. It is estimated that the gas-filled lamp developed by Langmuir represents an annual saving in the cost of domestic lighting in this country alone of £50,000,000. The improvement in the efficiency of the petrol engine due to lead ethyl saves over 2,000,000,000 gallons of petrol a year. The use of accelerators for vulcanising rubber has saved capital outlay on moulds estimated at £16,000,000. Research on motor tyres has increased their average life from 3,000 miles to over 20,000 miles."

"Naturally, these vast savings have been reflected in the profits, and prosperity of the industries and firms responsible for these great technical advances,"

"The time may come when the public will look at the research expenditure as an index of a firm's prospects; if those figures were all available to-day they might reveal the secret of many failures and successes."

The sixth pamphlet is an important one issued in Great Britain in October 1943, by the Federation of British Industries. It was prepared by a special committee of which Sir William Larke, Director of the British Iron and Steel Federation, was Chairman and of which distinguished scientists, engineers and industrialists were members. It was approved by the Grand Council of the F. B. I. It refers again to the Research Associations and emphasizes the need for intensive research by industrial firms. Some of its recommendations are worth repeating here:

"Every manufacturing firm should take stock of its position to ensure that it is devoting to research and development the maximum effort and funds, commensurate with the nature of its problems."

"Wherever possible it should maintain its own research department; where, however, this is not feasible, it should, at least, entrust one or more suitably qualified individuals with the responsibility for keeping constantly under review the application of research to its activities, and for initiating such investigations as may from time to time prove desirable, and create and maintain a special fund for such research and development of a magnitude compatible with its resources."

"That the firms comprising the industries which have their own collective research associations should give the most careful consideration now to the question whether they are making to their research association a contribution, either in money or in other ways, commensurate with the work which, if adequately supported, it could perform in furthering the interests of the industry as a whole."

"That every industry which has not created a collective research association should set up a co-operative research committee and take steps to create and

maintain a research fund which would equitably distribute the burden over the constituent concerns in proportion to their interest in the industry. The research committee would determine whether the scale and nature of the research needs were such as to require the establishment of a research association, whether a link could satisfactorily be formed with existing research associations, or whether research problems could be dealt with extra-murally through university laboratories and other research establishments."

"The Department of Scientific and Industrial Research should make the maximum use of the wide powers it possesses both as regards the amount of grant which can be made available in each case in relation to the countervailing contributions from the industrial subscribers to associations, and as regards the eligibility for grant of types of organisation for collective research which, though not research associations in name, are in fact fulfilling similar purposes."

"Financial provision should be made from public funds to enable the Department to increase and continue indefinitely financial support to research associations and similar organizations as a permanent feature of the national economy."

"That the Government should allocate to the D. S. I. R. an extra annual sum of at least £1 million for the maintenance and expansion of its activities."

The report refers particularly to the position of the scientist in industry. It points out that:

"the best results can only be obtained from a firm's research personnel if they are taken fully into the confidence of the management and given a definite standing in the hierarchy of the organisation. The research worker cannot be expected to perform his duties unless he has at his disposal all relevant information which is in the possession of other branches of the organisation of which he is a member."

It adds the reminder:

"It is also to be remembered that publication of the scientific aspects of his work is a legitimate ambition of every scientific research worker. Experience has shewn that such ambitions are not as a rule inconsistent with the interests of firms engaged in competitive industry; on the contrary such publication increases the prestige of the firm concerned."

Referring to the possibility of transfer between the research branches and the commercial or administrative side it states:

"Considerable benefit has flowed from the transfer of research workers having the requisite personal qualifications to commercial, administrative and other branches of activity. The more an organisation is staffed on all its sides by persons having an appreciation of science and research, the more progressive and adaptable to changing circumstances it is likely to be. Little benefit will be derived from increasing the numbers of those engaged on research if trained minds are not more fully employed in other branches of industry. The general scientific outlook of industry must be raised if the understanding and application of new scientific inventions, discoveries and developments by industrial concerns are to be increased. The first to exploit or apply a new discovery or invention reaps the major material advantage in increased employment and prosperity."

How well these words apply to Government as well as to industry. Let me alter a few words:

"The more a Government office is staffed by persons having an appreciation of science and research, the more progressive and adaptable to changing circumstances it is likely to be."

And again,

"the general scientific outlook of Government must be raised if the understanding and appreciation of new scientific inventions, discoveries and developments are to be increased."

Finally, one further quotations:

"The amounts spent by individual firms on research and development and by Research Associations on research represent a fraction of one per cent. of the

value of industrial production; if one per cent. of the total value of our industrial production were spent on research and development, the increased productive efficiency and employment capacity would yield an annual return of many times such expenditure."

The seventh article is one by Mr. Samuel Courtauld, Chairman of Courtaulds Ltd. It is reprinted from a "turnover article" in the "Times" of November 1st, 1943. It is a tribute by a great industrialist to the need of research for the benefit of industry.

The last four of these articles referred particularly to industry: but what is true of industry is true of most other forms of human activity. The same things could be said *mutatis mutandis* about agriculture, about health and nutrition, about tropical medicine, about fisheries, about transport and communications—and about the making of war; and I suppose it could be said also about those other fields of human activity to which the social rather than the natural sciences apply. It is important in any living growing society that all these interests and activities should move together—that none should grow unduly at the expense of another. For living growing society is like a living growing animal: its healthy functioning depends upon a proper balance between the various activities of its many mutually dependant parts. Perhaps I feel that so strongly because I am a physiologist, and every physiologist knows that each organ and function in the body is inextricably bound up with every other. A healthy society like a healthy body is adaptable and minor disturbances do not send it over the edge to disaster: but that is because all its parts are working closely together. In reading all these examples of the determination now evident in Great Britain to apply science more fully to industry, one must not be misled by any idea that its application to all these other branches of activity are not in mind too—but industry has to earn the money, or to make the goods and resources, without which these other very desirable applications of science will be starved and stunted.

The last paragraph in the series is a Progress Report of the Colonial Research Committee to which is appended a report of the Colonial Products Research Council. It shows that in fact various very different aspects and applications of research are in mind as well as the industrial ones. In 1940 the Colonial Welfare and Development Act was passed and in it provision was made for the allocation of £5 million per annum for colonial development plans and of £500,000 per annum for research. The object was not at all the exploitation of colonial resources and natural products in the interests of British or any other industry. If such exploitation of natural resources resulted, that would be as part of the overriding object which was the welfare of the colonial peoples themselves. There are sixty million people in the colonial empire and their general welfare is the trust of Parliament and people in the U. K. It is easy and cheap to sneer at decent motives and actions, but it is much harder and more expensive to do anything decent oneself; and in this case the motive, and the action which will result from it, were decent.

In time of War it has proved very difficult, with all resources used up or earmarked, to apply any effort either for research or for development which would have much immediate effect. In fact very little of the money allocated has been spent. In 1942, however, two bodies were founded, the Colonial Research Committee under the Chairmanship of Lord Hailey and the Colonial Products Research Council under the Chairmanship of Lord Hankey, F. R. S., with Professor J. L. Simonson, F. R. S., as Director. The former body has the wider scope and much of its activity has been directed to drawing up plans which it is hoped to implement as soon as conditions are better and as soon as men and resources are available. Its original members apart from the Chairman were all professional scientific men concerned with the natural sciences. They themselves, however, felt that research on colonial problems would be limited in range if the social sciences were omitted from its scope, and at their suggestion, the Secretary of State for the Colonies added an economist and a sociologist to their number.

The activities of this Committee will be closely linked, it is hoped, with the development of higher education in the colonial territories. Indeed the development of research and higher education must go hand in hand in the colonies as everywhere else. Two Commissions on Higher Education in the colonies have been set up, one to visit West Africa; the other to advise the Secretary of State for the Colonies on the development of institutions of university status and standards in the colonies. The Colonial Research Committee is in close touch with these Commissions on Higher Education through common membership and in other ways.

One special plan is referred to in the report (para. 59), *viz.*, that of offering a number of Research Fellowships to enable young research workers of established reputation to work in the colonies for a period of years and then to return to their previous posts in the Universities of the U. K. and elsewhere. In this way not only will good research work be done in and for the colonies but foci of interest in colonial problems will be formed in the universities. This plan conforms to recommendation No. 5 in the Report reprinted above of the British Commonwealth Science Committee.

The need of and the problems for scientific work in many of the colonial territories are much more similar to those of India than to those of the U. K. in India research has gone so far in various directions, *e.g.*, in the utilisation of tropical raw materials for new industrial purposes, that there would be great advantage in the work of the Colonial Research Committee if it could secure the closer collaboration of Indian scientific workers. Very often it has happened in the past that India could learn, and has learnt, from elsewhere; in this case it is likely that the boot will be on the other leg and that the initial advantage will be the other way round. Traffic, however, in scientific research is certain to come both-ways and the advantage will ultimately be to both parties.

In all these applications of science to problems of human betterment we must bear two things in mind. We must not be ashamed or afraid to go on mentioning them for they affect the policy to be followed. The first is that the motive of curiosity, of intellectual adventure, of trying to penetrate the unknown, of wanting to explore and understand, is the strongest impulse driving men—at least the men who are most likely to get there—to new discovery. The desire to benefit one's fellow men by such discovery or invention, present as it is in all decent people, is usually not the primary motive. If some people think that this is a sad fact, it is nevertheless a fact. Those who want to benefit their fellow men, but have not the divine flame of intellectual discontent and curiosity, will find little satisfaction in purely scientific work—for they will have very little success.

The phrase "pure science" defines the motive, not the object or the result of the research. If discovery of the highest value is to be achieved, those who have the divine flame of curiosity and scientific intuition must be left to pursue their object without too much direction to any purpose of immediate practical application. They may get their satisfaction in abstract physics or general biology, or they may get it equally in clinical medicine or chemical engineering. "The wind bloweth where it listeth and one heareth the sound thereof; but no man knoweth whence it cometh or whither it goeth." That may not be strictly true of meteorology today, but it is true still of scientific discovery. No man can predict its actual course or direction—no man can tell who will make it or how it will be used. All that we can say for certain is that on the average and in the long run the pursuit of knowledge is one of the most fruitful occupations of mankind and that to attempt to tie it down too closely to immediate practical results will be to deny it the possibility of growing to its full structure. In simple words, opportunities must always be given for the pursuit of science as a thing in itself and for its own sake, and a scientist must be valued by his fellow men and his fellow scientists for his capacity for original thinking and discovery, not for the financial or practical value of his results.

The second thing to bear in mind is this. In the application of science to the practical problems of industry or human welfare, it is no good leaving the

direction to practical men alone if these have no knowledge or experience of science. Such direction must be a joint concern between the scientist and the practical man, and among the practical men, as the report of the F. B. I. emphasizes, there must be some with active knowledge of science and experience of research. The scientist, some foolish man has said, must be "on tap but not on top." He need not be on top but he must in fact be treated as an equal partner in the enterprise of applying science to obtain a practical result. Without that equal partnership between science and administration or business, at the level of policy and direction, the best results will never be obtained.

A. V. HILL.

NEW DELHI;
The 1st January 1944.

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I. REPORT OF THE BRITISH COMMONWEALTH SCIENCE COMMITTEE.

29TH MARCH 1943.

Introduction.

The scientific problems provided by the war in connexion with technical devices and weapons, supply, medicine, public health, agriculture, food, communications, etc., have brought scientists from all parts of the British Commonwealth into close cooperation. The efficient organization of this work had necessitated the presence in London of scientific representatives of the various Dominions, and the opportunity was taken by the Officers of the Royal Society of instituting an informal meeting ground for the consideration of joint problems. The general objectives were to secure scientific cooperation in tackling the emergency problems of the immediate post-war period and to ensure that the most should be made of our common scientific resources after the war for improving both scientific knowledge itself and the life of the peoples of the Empire.

A conference was called at the Royal Society's rooms at Burlington House on 7 October 1941, in order to discuss the question in general; and, if thought fit, to appoint a committee, consisting of United Kingdom and Empire representatives, to consider means of promoting cooperation between the several parts of the Empire (a) in scientific research and (b) in the application of science to technical, biological, medical and economic problems. Representatives of the Dominions and India, representatives of the Royal Society, the Secretaries of the Research Councils, Lord Hankey and others were invited to the conference.

As a result a small informal committee was set up under the chairmanship of Sir Henry Dale, President of the Royal Society, and the following also agreed to serve:

Sir David Chadwick
Dr. L. E. Howlett (later Professor A. G. Shenstone, Canada)
Dr. H. C. Webster (Australia)
Mr. Nevill Wright (New Zealand)
Lt.-Col. B. F. J. Schonland (South Africa)
Dr. T. Quayle (Office of the High Commissioner for India)
Professor A. V. Hill (Secretary R.S.)
Sir Alfred Egerton (Secretary R.S.)
Dr. Alexander King, Secretary

At a later stage in the deliberations of the Committee a representative of the U.S.A. was invited to participate and various officers of the O.S.R.D. (Office for Scientific Research and Development) have attended meetings. Mr. Eastwood, Secretary of the Colonial Research Committee, and Professor W. E.

Le Gros Clark, a member of the Council of the Royal Society, attended the last few meetings.

This report summarizes the discussions which have taken place at the 12 meetings of the committee.

The discussions have purposely been of a somewhat general and exploratory nature. They have, however, been focused mainly on:

(1) Schemes for collecting and disseminating information, for example on the model of the Imperial Agricultural Bureaux;

(2) Schemes for collaboration in research within the Empire;

(3) Schemes for facilitating visits and readier movement of research workers, professors and others within the Empire.

The extension of such schemes to collaboration with the United States has been discussed.

During the discussions, reports have been received on the work of the Imperial Agricultural Bureaux, on the Industrial Research Associations of the D.S.I.R., on the organization of the N.R.C. (Canada), the C.S.I.R. (Australia), the D.S.I.R. (New Zealand) and the N.R.C. (South Africa), on the Indian research organizations, etc. Mr. A. L. Hetherington of the D.S.I.R.; Mr. Evelyn Shaw, Secretary to the Commissioners for the Exhibition of 1851; Dr. L. Haden Guest, Secretary of the Leverhulme Trust; Mr. J. G. Crowther, Secretary of the Science Committee of the British Council; and Mr. W. B. Brander of the Universities Bureau of the British Empire have attended the Committee and provided much useful information.

A complete discussion of topics, such as the grants available to students and others in different parts of the British Commonwealth, would have required a lengthy and detailed enquiry. The Committee has not attempted this, but has aimed at discovering, as far as possible, what is lacking in the existing machinery.

Throughout the British Commonwealth there are already in existence, in varying forms, governmental, semi-governmental, and independent bodies subsidized by government funds, administering or promoting research on problems of national importance. The existence in the United Kingdom of such bodies as the Medical Research Council, the Department of Scientific and Industrial Research and the Agricultural Research Council, and of similar or equivalent bodies in other parts of the Empire, is fundamental to the hoped-for extension and integration of scientific collaboration within and without the Empire. There has also been set up during the war a Scientific Advisory Committee of the War Cabinet responsible to the Lord President of the Council, composed of the President and the two Secretaries of the Royal Society and the three Secretaries of the Scientific and Industrial, Medical and Agricultural Research Councils, forming a central body which, as Lord Hankey has pointed out, should be able to facilitate cooperation in research within the Empire in time of peace. Similarly the Colonial Research Committee, established by the Secretary of State for the Colonies under the chairmanship of Lord Hailey with four of the same members, should facilitate cooperation in the colonial field as well as stimulate research there.

As an example of a central organization working for the whole of the British Commonwealth may be cited the Imperial Agricultural Bureaux. This system has since its inception in 1929 been an outstanding success in providing a vital service, collecting, collating and disseminating information on agricultural research to workers throughout the Empire and the world. The fact that this organization, administered by a constitutional and representative executive council sitting in London, has been continuously supported since 1929 by the whole Empire on the basis of an agreed contribution, surely implies that governments would be sympathetic towards an extension of such a scheme to other essential scientific services.

The implications of the Atlantic Charter point inevitably to the need for closer political, social and technical collaboration with the U.S.A., the U.S.S.R., China and other countries or regions. There is therefore a pressing need for

planning collaboration in well defined spheres of activity: firstly by the establishment of the best agreed cooperative machinery for exchange and dissemination of technical information and later by planning for cooperative research on problems common to all or to certain regions. As an example of such a regional scheme, mention may be made of a suggestion regarding African institutes of advanced study and research which was brought to the attention of the Committee by Colonel (now Brigadier) Schonland. He proposed that institutes for research on African problems might be formed in such subjects as:

Tropical diseases	Ethnology
Social Anthropology	Geology
Native languages	Geophysics and Meteorology

There are a number of bodies collecting and disseminating scientific information, which might be assisted if made part of a wider scheme. The case for collaboration in the production of scientific abstracts of high quality for the common use of the English-speaking world is very obvious, and would have the strong support of the Committee.

1. Bureaux of Information

(a) *The Imperial Agricultural Bureaux* are a group of 12 centres for the collection, sorting, indexing and abstracting of world scientific information on 12 branches of science bearing on agriculture. These branches are:

Entomology	Animal breeding and genetics
Mycology	Soil science
Animal health	Plant breeding and genetics
Animal nutrition	Pastures and forage crops
Dairy science	Horticulture and plantations crops
Forestry	Agricultural parasitology

Each is located at, but not as part of, a research institute specializing in the subject. All are under one and the same administrative body, *viz.*, the Executive Council of the Imperial Agricultural Bureaux. Each issues regularly an abstract journal, which sells all over the world. Their function is to serve investigators, spread knowledge and put research workers into touch with each other.

(b) *The Bureau of Hygiene and Tropical Diseases* has, for the last thirty years, been a centre for the collection and dissemination of information on diseases of the tropics and warm countries. Since 1926, its work has been extended to cover 'all branches of public health and preventive medicine, with particular regard to the needs of Britain overseas', while since early in the present war it has also been producing a *Bulletin of War Medicine* covering all branches of the science of medicine having application to war conditions. The Bureau is supported by the governments of the United Kingdom, the Dominions and the Colonies.

The Committee discussed the possibility of the extension of such information services in other directions, for the use of the English-speaking world as a whole. The number of journals and other publications dealing with different branches of science and technology, and providing abstracts of current literature in the several subjects is large; and there is duplication, as the following examples (c) and (d) illustrate.

(c) *British Chemical and Physiological Abstracts* is produced and published under the auspices of the Society of Chemical Industry, the Chemical Society, the Physiological Society, the Biochemical Society and the Anatomical Society of Great Britain and Ireland. Practically the whole of published information in pure and applied chemistry, biochemistry and physiology is recorded in these abstracts. *Chemical Abstracts* is published in America by the American Chemical Society and there seems reason to believe that closer collaboration might save duplication of effort and result in greater efficiency and completeness. The rapid extension of civil air transport to be expected after the war should make possible the simultaneous publication in the United States and the United Kingdom, of jointly prepared abstracts.

(d) The physical sciences, including mathematics, are served mainly by *Science Abstracts* which has both a scientific and a technical section, and is

edited and issued monthly by the Institution of Electrical Engineers in association with the Physical Society, the American Physical Society and the American Institute of Electrical Engineers. There is considerable overlap between *Science Abstracts and British Chemical and Physiological Abstracts.*

(e) There are (or were) international organizations for special purposes, such as that for the publication of *The Annual Tables of Constants*, formerly centred in Paris, which collected data of measurements and issued an annual volume. This organization has been re-started under new auspices but with the same French editor (M. Thon) in America.

(f) Many institutes, research laboratories and research associations have their own abstracting services which collect information bearing on the work of the particular laboratory or department, a service which is often very valuable. Building Research Abstracts, issued by the Building Research Station of the D.S.I.R., is an example of this activity. The Imperial Institute collects and issues a certain amount of information relating to natural colonial products.

With the growth of the microfilm service, libraries and information bureaux will probably in future be able to provide microfilm copies of published information to any individual worker, while interim reports or detailed information, which it may not be worth while printing, may be made available in the same way to other workers. Rapidity of dissemination of information could thereby be improved.

There seems to be need for a rationalization of effort in the provision of an efficient and widespread information service. The Agricultural Bureaux are maintained by a central organization, though working in separate institutes, and the same principle might be extended to cover the whole, or at any rate a wider field. The advantages would be: greater financial stability, prevention of duplication and a closer coordination of the whole information service. This rationalization of existing British organizations throughout the Empire might be regarded only as a first step. The ultimate objective should be to rationalize abstracting and other scientific information services throughout the English-speaking world.

The Committee considered that this whole issue would have to be the subject of detailed enquiry before any definite proposals were put forward. In view, however, of the growth complexity of science and technology and the penetration of science into almost all human activities, it seems essential that efforts should be made to provide as efficient an information service as possible. In order to implement the clauses of the Atlantic Charter, will there not be need for the orderly economic collaboration of nations? Suggestions have been made from time to time that information collected by individual countries should be brought together to a central United Nations Economic Bureau (or Bureaux). Scientific research and technical development have a fundamental bearing on economic factors, and it is very necessary that the organization in each country for the collection and correlation of scientific information should be of such a kind that it would aid the collection of data by the economic bureaux.

2. Collaboration in Research—

(*a*) *Coordination of Common Scientific Services.*—The Committee agreed that in principle there is a strong case for promoting collaboration in research on common problems, because such collaboration would inevitably facilitate the attainment of specific objects to the benefit of all. The following resolution of the New Zealand Council for Scientific and Industrial Research is typical of the desire to support such collective efforts.

"That this Council fully supports the principle of coordination and collaboration in research work as a means of promoting progress to the advantage of all countries and is willing to consider any specific plans towards that end."

The National Research Council and the National Research Board of South Africa are also whole-heartedly in favour of the more easy interchange of scientific workers of every kind, and agree in principle to the setting up of a 'permanent imperial scientific liaison committee' which should do valuable work in keeping workers in places remote from the great centres of scientific activity informed of what is going on and in making the best use of them for the general

good. Collaboration on problems in medicine and agriculture may be easier and simpler to arrange than in industry where conflicting interests sometimes impede close collaboration. Nevertheless, the Committee were informed, many of the United Kingdom Industrial Research Associations have Dominion members, collaboration is well extended and its advantages were appreciated.

(1) *Empire Supported Organizations.*—There are already in being within the Empire a number of cooperative research services, and one for locust research which is financially supported and administered within the Empire, but covers foreign territories as well as British.

The Imperial Institute of Entomology and the Imperial Mycological Institute, in addition to their information services, aid in the identification of insects and fungi. The staff attached to the Farnham House Laboratory searches for parasites of insect pests and sends them to entomological departments. At Cambridge, work in genetics is in progress on potatoes collected from the Andes. These various activities are financed cooperatively by Empire governments and are administered by the Executive Council of the Imperial Agricultural Bureaux.

Several oversea governments—in the Dominions, India and the Colonies—contribute towards research activities in the United Kingdom on subjects in which their countries are particularly interested; for instance, in the Wool Industries Research Association, the Food Investigation Board (D.S.I.R.), the Imperial Forestry Institute, etc. The work carried on by the Pest Infestation Research Committee, now financed and administered by the D.S.I.R. (U.K.), developed from that started by the Empire Marketing Board and, thereafter, carried on for a few years on a cooperative basis under the Executive Council of the Imperial Agricultural Bureaux. It is engaged on vital research and control work on pests attacking grain and other foods and raw materials, when in store. Since losses from such causes are universal and in the aggregate immense, there would appear to be urgent need for international collaboration to develop reliable methods of preventing the spread of these pests.

Just before the war steps had been taken towards placing on an international basis the work of the International Locust Research Committee which is centred at the Imperial Institute of Entomology. Widely based international cooperation to control depredations by locusts would seem obviously desirable.

(2) *International Organizations.*—Among these were the international bodies which provided a common service, *e.g.*, the International Bureaux of Weights and Measures in the Pavillon de Breteuil, Sèvres, Paris; and the International Unions which before the war arranged through their meetings for cooperation in several branches of science—scientific radio, astronomy, meteorology, geodesy, etc. There were also oceanographical and zoological laboratories which were almost international in character. The High Altitude Research Station on the Jungfraujoch provides another case of international cooperative research.

Further examples of international collaboration were to be found before the war in various health organizations such as that of the League of Nations, the Office International d'Hygiène in Paris and the International Health Board of the Rockefeller Foundation of New York.

Before the war there were also world organizations, such as the International Institute of Agriculture (Rome) and the World Power Conference (Paris), making valuable statistical or technical compilations and investigations in regard to agriculture and the fuel industries respectively throughout the world, and providing centres of information thereon. There would appear to be room for an international body to perform similar service in relation to the world's mineral resources.

Most of the essential services mentioned above will need to be reviewed and revived in the most suitable form and on as widely international a basis as possible, after the war. Anglo-American initiative may be required to re-establish

such co-operation. Machinery for close collaboration in research and the establishment of laboratories and institutes common to the Empire or the world, will require further consideration.

(*b*) *The Promotion of Research on Common Problems.*—A host of important problems of world-wide significance are being investigated independently in Empire countries and elsewhere. Many of these researches are wholly financed and administered by governments through departments of state or other organizations. Advantage would result from cooperation between those countries willing to pool resources for the common good.

Some of the problems are common to all countries: others only to parts of the Empire. They cover a very wide range of subjects and many are of great importance; they include, for instance, food production and preservation, packing and transport; nutrition and dietetics; human and animal diseases; plant physiology and pathology; soil erosion; production of raw materials; treatment of minerals, fibres, oils; industrial problems; aeronautics and navigation; communications and defence.

In addition there are many problems which should be immediately tackled, relating to the production and storage of foods of high nutritional value to be used in the immediate post-war period for feeding the people in the devastated areas. These problems, apart from any other considerations, demand immediate cooperation in the technical field. They are problems which must be solved if the provision of such foods is to become practical and sufficient.

Further problems which might be considered are connected with improvements in the efficiency of public services such as power, transport, fuel, housing, roads, water, sewage, etc., most of which are the subjects of research by governmental organizations in one or more countries of the British Commonwealth and are related now to programmes of post-war reconstruction.

There are also geodetic surveys throughout the Empire and a number of other subjects such as magnetism, meteorology, scientific radio, ecology, oceanography, ethnology, etc., in which collaboration within the Empire will be needed after the war, both from the purely scientific and the applied scientific points of view. The researches which may be undertaken by the recently established Colonial Research Committee under LORD HAILEY'S chairmanship should also be coordinated with work in the Dominions and other parts of the Empire.

3. **Organization of Collaborative Research—**

It is sometimes suggested that a large comprehensive organization should be set up to plan and integrate scientific effort within the Empire. The fundamental difficulty in establishing such a body would be that the most active people responsible for organizing scientific effort in the several parts of it could very seldom be brought to consult together. It would seem better so to modify *existing* organizations as to make close collaboration possible.

Each government concerned should, we suggest, maintain in London one or more liaison officers with scientific and technical experience, whose duty it would be to represent their governments on scientific matters, to explore new scientific developments in the United Kingdom and to make arrangements in connexion with the increased exchange of scientific personnel which we envisage. These representatives would attend meetings of scientific bodies (official and unofficial) when desired, and might, together with United Kingdom representatives, and acting with the Royal Society, constitute a British Commonwealth Scientific Collaboration Committee for the discussion of the topics of common interest: representatives of colonial interests should be included in this committee. It would report its conclusions to the High Commissioners for the Dominions and for India, and to the United Kingdom Government through the appropriate channel which, in many cases, might be the Lord President's Scientific Advisory Committee.

Such an organization would in no way preclude special committees from being set up, or conferences called, to consider particular matters, under the ægis either of the Royal Society or of the several departments of the Governments in the United Kingdom, the Dominions, India, etc. In fact, direct

collaboration in research is as likely to flow from increased opportunities for personal visits between scientists in the various countries as from any other source; and joint schemes for research, involving official participation, will frequently result from the recommendations of special conferences attended by the administrative and scientific heads of national research organizations and by selected scientists skilled in the subject. Such conferences, however, cannot be in permanent session. A standing British Commonwealth Scientific Collaboration Committee, with the contacts suggested, should be of value in maintaining information about research in progress, in preparing the way for specialist conferences, and in making from time to time proposals for cooperative action.

4. **Flow of Personnel—**

The Committee surveyed the question of grants available to scientific workers both in the United Kingdom, the Dominions and India, grants not only to enable them to carry out research work in various universities and institutes, but to allow them to move from one centre of research to another, or to travel from one part of the Empire to another. It was clear that grants for students to travel were more readily available than grants for senior workers (of the lecturer and junior professor standing). As there are between 2,000 and 3,000 professors, assistant professors and readers or senior lecturers in the various universities of the Empire, it was estimated that thirty times the present available funds for facilitating visits could well be used. It is, however, not only provision for academic staffs which should be made, but also an extension of present facilities for graduate students, industrial scientists, and scientists working in government institutions. Besides short visits, arrangements for longer periods might often be very valuable to all parties. All this would certainly be very valuable in the Colonial Empire, in making colonial problems better known and in bringing knowledge and experience gained elsewhere to stimulate local research workers.

Freer interchange should take place also during early post-graduate years, particularly for vocational training. If financial arrangements could be made, excellent results would be obtained in higher technical education by the freer movement. A successful example of this type of collaboration is the Rockefeller Foundation's scheme for selected British medical students to pursue their clinical studies in American and Canadian universities. The continuation of this scheme on a reciprocal basis seems highly desirable.

The Committee considered that funds should be made available to enable senior research workers to visit and work in other parts of the Empire, by arrangement between the employing bodies. Air transport after the war will make travel much quicker, and if funds are available should greatly facilitate closer collaboration. This provision of additional funds for making travelling possible to scientific workers is therefore a foremost recommendation of the committee. This conclusion was sympathetically received both by the secretary of the Leverhulme Trust and by the secretary of the Scientific Committee of the British Council. The functions of the recently appointed trustees of the Nuffield Foundation would seem to include the possibility of support from that great new benefaction.

It was stated by MR. EVELYN SHAW that, if funds were available, the number of 1851 Exhibition Scholarships awarded could be nearly doubled without in any way lowering the standard; and, in view of the excellent results achieved by the 1851 scholars*, it would seem worth while to increase the funds available for this class of worker. The Colonial Research Committee might be able to assist in such a project, so far as the Colonial Empire is concerned.

There is need for a closer study of the grants available for the encouragement of scientific research in the several parts of the Empire, including the provision of research studentships and fellowships, and consideration should

* Between 8 and 9 of the 700 scholars have already been elected into the Fellowship of the Royal Society.

be given to the possibility of instituting a scheme of sabbatical leave for members of the scientific and technical staffs of university departments, government laboratories, research associations and the like.

5. Recommendations

1. That the Royal Society should invite representatives of the appropriate scientific, technical and official bodies to meet as early as possible this year:—

(*a*) to discuss in general the further development of *abstracting and information services* as a cooperative effort between English-speaking countries; and, if agreed,

(*b*) to propose machinery

(i) for making a more detailed inquiry, and

(ii) for formulating more definite plans than are embodied in these recommendations.

2. That a suggestion be made to the governments of the various English-speaking countries that they should consider the possibility of maintaining *permanent scientific and technical representation* in London and possibly also in other capital cities of the English-speaking world.

3. That if scientific and technical representatives of the Dominions and India are permanently established in London, these, together with official representatives of science in the United Kingdom and the Colonies, should be constituted a *British Commonwealth Scientific Collaboration Committee*, to act with the Royal Society in the discussion of topics of common interest, to keep in touch with all agencies and organizations for the collection and dissemination of scientific information, to further schemes for cooperation in research, and to make such recommendations and proposals for common action as seem fit.

4. That if scientific and technical representatives of the *United States and of other countries outside the British Commonwealth* are established in London, arrangements should be made to seek their cooperation, so far as practicable and appropriate, in the work of the British Commonwealth Scientific Collaboration Committee.

5. That the attention of the governments concerned, and of independent agencies, should be called to the very great value of frequent and easy *personal contacts and exchanges* between research workers, and students, in various countries, which air transport should greatly facilitate in the future. For this purpose, largely increased funds would be required, and some plan for coordination would need to be worked out with the various grant-giving bodies.

6. That the attention of the various governments, of universities and of other authorities be drawn to the advantages which would result from the institution of a system of *sabbatical leave*, to enable the scientific and technical staffs of academic, government and industrial research organizations to make fuller use of such facilities as may, from time to time, be available for visits to other parts of the English-speaking world.

II. PARLIAMENTARY AND SCIENTIFIC COMMITTEE

An unofficial group of members of both Houses of Parliament and representatives of certain scientific and technical institutions

Scientific Research and the Universities in Post War Britain

PART I. THE NEED FOR INCREASED RESEARCH

(a) General

1. If we are to improve our standards of living after the war and to maintain our position in the world, research in many categories will have to be undertaken on a scale not hitherto contemplated in peace-time. The resources upon which we depend for our schemes of reconstruction and social betterment will have to be used and developed with the maximum vision, intelligence, and enterprise.

This can only be ensured by the application of active and well-directed technological research firmly based on the foundation of scientific discovery.

2. Britain cannot afford to fall behind other nations in this essential task of research, if only because of its density of population, and its position as the centre of a wide empire. If we are to maintain our position we must take full advantage of the native ability of our scientists and engineers, and the intelligence and craftsmanship of our workers. Our industry will have to concentrate increasingly on the manufacture of products which demand a special degree of intelligence and technical skill in the making. Science will have to be applied increasingly to ensure the best use and maximum yield of our soil, animals, forests, fisheries and mines, and the development of our colonies and protectorates, as well as the maintenance of health and the prevention and cure of disease.

3. In the period between the two world wars we began to lose our pre-eminence in production to later entrants in the field. The work of our scientists and technologists since 1939, however, has demonstrated conclusively that this was not due to any diminution in our native talent. We should do well to give this ability ample scope in the peace that lies ahead.

4. Modern creative scientific work is largely a matter of teamwork directed by first-class brains, but this has to be followed by practical application and testing, calling for large numbers of scientific and technical personnel. For these the present scale of our provision of university and technical education is below that of either the U.S.A. or U.S.S.R. and calls for immediate steps to secure expansion—since the building up of research schools is a matter of years and the training of the personnel cannot take place on an adequate scale until this has been done. Indeed, it is probably for this reason that our failings have not, so far, been more fully revealed, since the results of the huge scientific investments of America and Russia were not due to make themselves effectively felt until (say) 1950, by which year they would (leaving the war out of account) have been overwhelming.

5. According to recent estimates the university income of the U.S.A. (population 133 millions) is more than 10 times greater than that of Great Britain (population 46 millions) and her total research expenditure, £70,000,000 a year, at least 10 times as large.* It has also been stated that the expenditure of the U.S.S.R. on research and universities is on a similar scale to that of the U.S.A. Such comparisons are admittedly rough and tend to neglect hidden assets and endowments in an old-established country like ours, but they cannot be ignored, and certainly provide a significant indication of pre-war trends.

6. In this country the problem has, in many respects, been approached with less energy and foresight, but there are now encouraging signs that we are beginning to appreciate the need to revise the scale of our efforts. We should certainly look forward to spending at least 10 times as much annually after the war if we are to provide the basis without which neither our agriculture nor industry can effectively meet the needs of the future.

(b) **Fundamental Research**

7. It has been represented to our Committee that there should be a considerable development of fundamental or pure research in the United Kingdom. We are beginning to live too much either on past endowments or on private benefactions from abroad, *e.g.*, on those of the Rockefeller Foundation. It is, however, essential that this country should continue to play its full part in this

*Total expenditure in the universities and university colleges of Great Britain was £6·7 millions in 1938–9. The total research expenditure in this country has been variously estimated, the highest figure being £7 millions, given by Lord Falmouth in the House of Lords, 22nd July, 1943.

Total expenditure in all universities and colleges of the U.S.A. (excluding Junior Colleges) was $420 millions in 1935-36; that of the 150 major universities was $265 millions. The total research expenditure of that country exceeded $300 millions for 1935-36. (National Resources Planning Board: Research—a National Resource, Part I, Section 6.) Recent estimates have been of the order of £70 millions.

vital work of research. Applied science cannot live on the fundamental discoveries of past generations. Unless fresh discoveries are made it dies of inanition. Moreover the search for truth has always been an essential accompaniment of higher education, and teaching becomes ineffective if research aimed at the extension of knowledge is allowed to languish. Such research, however, cannot be confined to universities. Industrial and Government research organisations have also an essential part to play. But wherever fundamental research is conducted it is clear that the Government will have to give far greater financial assistance and encouragement in the future than it has in the past. In this connection we have the valuable assurance given in the House of Lords by the Paymaster-General Lord Cherwell (20 vii 43) "that it is the policy and intention of H.M. Government to increase their assistance to pure research," and that he would "welcome any developments in industry in a similar direction."

(c) Agricultural, Veterinary and Medical Research

8. Agricultural, veterinary and medical research in Great Britain are co-ordinated respectively by the Agricultural and the Medical Research Councils. There is need for expansion in both these fields with due regard to the danger of sterilising research by its over-regimentation under the committee system. The maintenance of a prosperous, efficient and numerous agricultural community in Great Britain after the war, in the face of competition from overseas calls imperatively for increasing activity in the application of agricultural science. The present Minister of Agriculture has shown that he is fully alive to this fact. If we neglect to apply agricultural science to the full, the cost of the protection that will be necessary to make British farming pay may prove unacceptable. As Lord Bledisloe recently pointed out, although our agricultural research workers have made discoveries of great value we have failed until recently to be active enough in bringing the results of such research on to our farms or into our practice of husbandry.

9. The desirability of continual improvement in the fields of medicine, surgery and industrial and public health is accepted without question and has been given additional emphasis by the relevant passages of the Beveridge Report. The organisations under the purview of the Medical Research Council are vital to the national well-being, but in the words of Lord Dawson of Penn, "they should be much more substantially supported in the future than they have been in the past." Possibly a wider view might, with advantage, be taken of the functions of this Council to include the assistance of research in branches of science allied to medicine. The inter-relation of animal and plant diseases and deficiencies also needs further and more precise investigation.

10. The future impact of biological advances in agriculture, medicine, nutrition and sociology may well be of the same national importance as that of physics and chemistry in the past 50 years. There will have to be a special survey of the place of biology in reconstruction, with an expansion of research and the formation of further chairs at the universities in special subjects connected therewith, such as genetics, ecology, biophysics, biochemistry and various branches of veterinary science. In all these fields at the present time Britain's equipment is unworthy of her responsibilities.

(d) Industrial Research

11. Industrial research in Great Britain is mainly conducted by private firms in their own laboratories, but we have also our admirable scheme of co-operative Research Associations for various branches of industry. The latter are aided by grants through the Department of Scientific and Industrial Research which is also responsible for certain Government research establishments. The estimated expenditure of this Department for 1942-43 is £678,596 as against £657,850 for 1937 and £446,214 in 1928. There is a recognised need for large-scale expansion of all these organisations and with adequate encouragement from the Government there can be the most beneficial development as soon as the war is over. In the following two paragraphs we give a few examples of this recognition.

12. The Institution of Electrical Engineers has issued a report, in which the outlines are sketched of a British Electrical Research Board. The British Institution of Radio Engineers has made proposals on somewhat similar lines with regard to radio engineering. The recently established Gas Research Board is embarking on an ambitious programme. The Federation of British Industries has appointed a strong committee to report on the problems of Scientific Research in Industry, and we understand it is likely to recommend a substantial expansion of the work of the industrial research associations. Manchester University has appointed a committee which, in the words of the Chairman, Sir Ernest Simon, "hopes to publish a report which will indicate how our scientific teaching and research should be expanded and how our relations with industry may be developed." The Parliamentary and Scientific Committee, in a separate report issued in June, 1943, recommended an early and substantial expansion of the research work devoted to the utilisation of our unique natural resources of coal and the indications are that such expansion is already beginning to take shape. Already the mine owners have indicated their intention of spending an additional sum of £400,000 to £500,000 for such purposes up to the end of 1945. Dr. H. Moore, Director of the British Non-Ferrous Metals Research Association in a recent paper entitled "Co-operative Research in the Metal Industries" has shown the need for a large development of the Research Association movement during the period of reconstruction with particular reference to metal research. A sum of £500,000 p.a. has recently been made available by the Government for projects of colonial research.

13. Sir William Larke at a meeting of the Royal Society of Arts (February 1st, 1943), stated that through industrial research alone can we regain even in part our position as premier exporting nation of the world. Lord McGowan emphasised the same point in the House of Lords (July 15th, 1943) and at the last annual meeting of Imperial Chemical Industries. Mr. Oliver Lyttleton, Minister of Production, in a recent speech about the future of British industry declared: "It is towards the creation of demand and to the use of inventions that the economic thought of our specialists must be directed. Mr. Samuel Courtauld has advised members of the Rayon Federation that their research should be increased. He pointed out that all the big textile manufacturing nations of the world spend far more thereon proportionately than we do. He urged that State expenditure on research should be launched on a "revolutionary" scale and that there should be some remission of the present fiscal burdens on private research. Sir Harold Hartley, in a pamphlet just published, has written, "It is impossible to avoid the conclusion that if this country is to maintain its position in the world markets, our industries must greatly increase their attention to research as soon as the progress of the war makes it possible. There is danger in delay: markets once lost are not easily regained; and industrialists must take active steps now to organise this aspect of their post-war activities."

(e) University Research

14. In relation to science the universities have a dual function of training scientific workers and conducting fundamental research. The financing of university research is inadequate under modern conditions. The ordinary expenses of research are usually paid out of the general laboratory grant from university funds, which are often insufficient. For special or costly apparatus or special staff, the professor may frequently have to go cap-in-hand to one or more of a variety of bodies. The procedure is time-wasting, and sometimes humiliating and disheartening.

15. Although private benefactors have repeatedly come to the rescue in times past (when taxation was less onerous), the necessary funds in future years must come increasingly, and preponderantly, from the State. The present Treasury grant (made through the University Grants Committee to which we refer later) will have to be increased to allow more adequately for the normal cost of running the research laboratories of the universities. It is to be hoped, however that industrial firms, and individuals will continue from time to time to provide additional funds for special purposes in which they are interested.

16. For the provision of special costly apparatus the most appropriate body for administering Government assistance would be the Royal Society. This Society at present administers a Government Grant-in-Aid for Scientific Investigations of £7,000 per annum. The amount is far too small and should obviously be increased not less than ten or twenty times as soon as practicable. It should also be noted that if the desired expansion of scientific research, and more especially research in pure science, takes place, adequate provision must be made for publication of the results. Increasingly great demands will therefore be made on the resources of those scientific Societies which are mainly responsible for such publication. There is at present a Parliamentary Grant-in-aid for Scientific Publication: amounting to £2,500 a year for the Royal Society and the Royal Society of Edinburgh. This Grant-in-aid is used to assist in meeting the cost, not merely of the publications of these Societies, but also of the adequate publication of scientific matter through other channels and in other ways. Provision should be made for a considerable increase of this Parliamentary Grant-in-aid.

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17. *Summary. Part I.*—In the period 1919—1939 we began to fall behind other countries like the U.S.A. and U.S.S.R. in the scale of application of scientific research to technological development in many fields. During the present war our scientists and engineers have demonstrated that their capacity and inventive genius is unsurpassed. It is now recognised that in the post-war period in Great Britain research and its application must be on a far bolder and more imaginative scale than in the period 1919—1939. We ought, in fact, to look forward to spending at least 10 times as much annually after the war on research and development in order to provide the necessary basis without which neither our agriculture nor industry can meet the needs of the future.

PART II. THE SUPPLY AND TRAINING OF RESEARCH PERSONNEL.

18. To enable research work to be adapted and expanded to the peace-time requirements which have been briefly sketched it is obvious that there will have to be an equivalent adaptation and expansion of the present supply of scientific personnel.

This will be obtainable from two sources:—

(a) Existing scientific workers released from temporary war-time employment, the Services and armament work and trained (as necessary) for new peace-time research requirements.

(b) Increased output of scientific graduates from the universities and technical colleges.

19. The sum total of research which can profitably be undertaken is strictly limited by the number not only of inspired leaders but of trained workers available, and its quality depends largely on the knowledge and scientific acumen which the latter bring to the task. That their productiveness can be much increased by providing them with suitable laboratories, equipment, and adequate auxiliary staff goes without saying, but the production in sufficient numbers of the right men with the right training is the first essential in any extension of research.

20. The need for action is of peculiar urgency because we have in the technical branches of the armed forces and the Supply Departments a considerable reserve of scientific intelligence which will need to be guided into appropriate channels when the war is over. It will obviously not be necessary for *all* young scientists engaged in war research to undergo retraining at universities or technical colleges, and many of them will have gained most valuable practical experience in large scale industrial production or other work. The problem as regards many of these men will be to provide means to assist them in learning the requirements of peace-time industry or to tide them over the period before industry gets reorganised. Industrial firms may be reluctant to offer adequate remuneration to men with no knowledge of the particular business. In any

industry where a Research Association exists the latter may to some extent provide the necessary facilities, but a systematic approach covering the whole of British industry is a matter of real urgency. We have therefore been particularly glad to learn of the appointment of a special Committee to deal with these matters. Considerable funds will be necessary to enable the objective to be realised without serious loss of time.

21. Owing to the foresight of Lord Hankey and the Committee responsible for the preliminary training of the younger of these men, many of them have had substantial, though incomplete, university training in physics, chemistry, engineering, radio, etc., though not in the biological subjects, and should be able to complete a broader course of education within one or two years. The Government has already recognised the important part which can be played by these men in the post-war effort, and has initiated a scheme by which they will get training grants on demobilisation. This is referred to in paragraph 99 of the White Paper on Educational Reconstruction.

22. For the training of research workers this country has looked and must continue in the main to look to the universities. With the possible exception of one or two of the best technical colleges, there are at present no other institutions in this country capable of providing the wide and accurate knowledge and the strict mental discipline essential for research workers other than those whose principal work will be of a routine nature. Our universities must, therefore, be re-equipped and expanded to deal with considerably greater numbers of science and engineering students than heretofore.

23. We have more than doubled the output of engineers and physicists during the war. The implementation of any thoroughgoing post-war reorganisation of research and technological development will require an equal or even greater expansion in trained personnel. Our universities will, therefore, need to handle ultimately something like two to three times the 1938-39 number of science and technology students on this account plus the further increase for developments foreshadowed in connection with science teaching in schools. Academic staff, and above all buildings and equipment, will have to be found to deal with these increased numbers. The problem is large and complex and must be faced in good time. In 1938-39 there were in all 50,000 full-time students in the universities of the United Kingdom, of whom under 13,000 were studying science and technology, just over 1,000 agriculture, and 13,600 medicine and dentistry. These were accommodated in 16 universities and 4 recognised university colleges. There can be no question of reducing the numbers in other subjects in order to get more scientists—indeed, the increased need for teachers under the Educational Reconstruction programme, apart from other demands, will cause an increase in all subjects. We have, therefore to look to a rapid growth of the number of science students, and possibly to an ultimate doubling of the total numbers enjoying university education.

24. As those of our universities which now have 5,000 or 6,000 students are probably near the maximum desirable size, this implies a great expansion of the remaining establishments and possibly the development and promotion of some existing establishments such as the university colleges, to university rank, or even the foundation of new universities.

25. The immediate urgency of the subject is due to conditions caused by the war, but the increased facilities provided will not become redundant when the preliminary rush is over. If research and development are to be maintained at the level which circumstances demand, there must be a continuous output of highly-trained workers in all branches of science and technology. We regard a permanent increase in our student population as a national necessity. If the amount of research necessary to keep this country abreast of the times is initiated and industry reconstituted accordingly, the post-war problem will in due course be not to find jobs for men trained in science, but to find such men for the jobs. Many years are required for the production of a trained scientist. It is therefore not too soon to consider our requirements for 1950.

26. One of the war-time measures for ensuring the necessary flow of students through universities and higher technical institutes which must be continued and possibly developed further in some form or other is the system of State Bursaries and Engineering Cadetships. They should be extended to the biological, medical, veterinary and agricultural sciences, not yet within its ambit. In the national interest, these Bursaries should be available to all scholars, showing sufficient ability and personality to profit by a higher education. The Norwood Committee has stated in its summary of recommendations:—

"The winning of a college scholarship at Oxford or Cambridge or a university scholarship elsewhere should constitute a claim upon the public funds for assistance towards the cost of living at the University subject to evidence of need," and also

"The final award (of State and local Education Authority scholarships) should be made by the State which should bear the cost of scholarships. The value of the scholarships should be such as to enable the holder to take full part in the life of the university."

We hope that these recommendations will be generously implemented by the Government, but with due regard to the different educational conditions obtaining in England and Scotland and to the desirability of allowing the universities to have the final say in the maintenance of their own standards.

27. To meet with these and other problems with which they will be faced immediately demobilisation begins, the staffs of the universities will have to be increased. For this purpose they will need to recruit men of ability as the latter are released from their present war-time posts, but in view of the increased cost of living, the present low scale of university stipends will need to be revised if the right men are to be attracted and retained. To cope with the immediate post-war influx referred to in para. 25 there should be priority of demobilisation for university teachers from Government service.

28. Greater aid should also be available for young graduates who wish to continue studies for a higher degree, and who could at the same time give help and gain useful experience in demonstrating. At present there is a dearth of post-graduate scholarships and even more of post-doctoral fellowships. Sums need to be made available for this purpose. There would, however, appear to be considerable justification for suggestions put forward that a proportion of the staffs of industrial Research Establishments should be recruited from recent graduates, in order that training as investigators and the acquisition of what might be termed technical, rather than, fundamental knowledge, should take place in the laboratories of the industry concerned.

29. The present inadequate D.S.I.R. grant for students in training for research does not normally exceed £120 p.a. at universities other than Oxford and Cambridge. It should be increased so as to allow the student to take part on an equal footing in the activities of his fellow students since these form a part of his training for industrial and other research and are no less valuable than his work in the laboratory. At the present time these D.S.I.R. grants do not exceed 100 in number and they need expansion in number and value as well as in the range of subjects which they cover. They should be given without any geographical ties and should be available for use in any suitable university or research institution whether at home or overseas. When desirable they should be sufficiently generous to permit a certain amount of travelling. The medical and agricultural sciences should be similarly provided for through the Medical and Agricultural Research Councils.

30. Universities might also usefully arrange advanced courses of lectures by specialists from industrial and Government laboratories as well as from other universities. These might also be made available to non-members of the university so as to provide an opportunity both for keeping industrial scientists in touch with modern, academic work and academic scientists informed of developments in applied fields. As Sir Lawrence Bragg has pointed out, everything possible should be done to ensure a greater and better organised interchange of

scientific personnel between industry and our universities. It is desirable that facilities should be provided in suitable cases whereby industrial scientists be seconded to universities both for research and teaching. Opportunities should also be provided for academic scientists to carry out research in industrial laboratories. Industrial concerns should be encouraged to make such special facilities available wherever possible.

31. The rapid development of scientific knowledge and techniques makes it difficult for many individuals to keep abreast of their own and allied subjects once they have left the universities. Moreover, during the war many young scientists have over-specialised in a particular subject because of war requirements. Such individuals could receive great assistance at post-graduate refresher courses. These courses could deal both with recent developments in a broad field or with special problems and particular technique.

32. In the case of university teachers proper the financial position is only slightly better. An enquiry conducted by the Association of University Teachers in 1937 in universities other than Oxford and Cambridge showed that the average salary of all grades of lecturers at the age of 30 was only £313. This compared with £354 for a secondary school teacher and £400 for the Civil Service scientist. (The latter, incidentally, is paid only about two-thirds the average for the administrative grade and such differentiation is, in the opinion of this Committee, entirely without justification.) It is true that in some cases the basic salaries are supplemented by examination, coaching and similar work, but this sometimes involves an undue interference with the exercise of a capacity for original research at a time when that may be at its highest level in the early thirties. To encourage the man with a bent for teaching, as well as the man keen on research, to stay on at a university after graduation and give his best, an overhaul of the system of salaries and grants is needed.

33. Direct Government assistance to universities now takes the form of an annual grant from the Treasury of £2,250,000 per annum, its allocation being in the hands of a Treasury Committee, the University Grants Committee with a permanent full-time Chairman, Secretary and Assistant-Secretary. In addition local authorities and other Government Departments provide just over another £1,000,000 p.a. The Treasury grant will have to be substantially increased, say, to £6,000,000 or £7,000,000.

34. University buildings and equipment, including libraries, will also call for re-equipment and enlargement. This calls for capital expenditure of considerable magnitude and priorities of a high order if there are to be adequate facilities for the large number of post-war students envisaged. A sum of at least £10,000,000 may have to be spent over the first 5 post-war years for this purpose.

35. We presume that the University Grants Committee must shortly be considering immediate needs of the universities, both as to capital expenditure and income, to enable them to carry out adequately the vitally important duties which they will be called upon to undertake when demobilisation begins. We hope that in such event they will consult industry and the professional institutions, that their findings will be bold and that the Government will implement them generously.

36. It is doubtful if the University Grants Committee as at present constituted, has either the powers or the machinery for setting in motion the major changes now required. Its present constitution excludes membership by those actually engaged on University work, and it is without any representative of the "users" either of university trained personnel or of the results of University research. It can represent to the Treasury the case for expansion and recommend allocation of the funds available, but it lacks any power to consider University policy as a whole or to advise the creation of new chairs, new departments or new universities.

37. We regard it as vital to preserve the present freedom which the universities enjoy from control by the Board of Education or other Government Departments. This is a most valuable feature of our educational

system. If, however, the universities are to ensure the best use of the increase of State assistance and of co-operation with Industry which we contemplate, we think it desirable that they should take suitable steps to establish an effective Advisory Council which will be able to effect co-ordination and eliminate any unnecessary or wasteful overlapping. Particular universities may have to concentrate on special fields of training and there may well be a need to carry out a general survey and ensure efficiency all round.

38. The universities already possess in the unofficial Committee of Vice-Chancellors and Principals the nucleus of such a central body. It is desirable, however, that representation should include the teaching staff of the Universities and persons of distinction, in industry, medicine, agriculture, education, the government services, etc., in which University graduates are employed. A single body of this kind, however, would be too large and unwieldy for efficient operation and a smaller University Council should be formed from it. Special interests would be dealt with by special sub-committees.

39. This Council would be set up by the university interests themselves in consultation with the other interests concerned. It would thus in no way encroach on the essential freedom, diversity, integrity or independence of our universities. It would help to ensure that these essential privileges are not endangered by any charges of waste, inefficiency or confusion and provide a satisfactory answer to those who may suggest that there can be no substantial increase of university grants without introducing some measure of Government control. This in our view it is imperative to avoid.

40. A further problem that should also come under review in this connection is the need for recognition that science is an essential ingredient in all education and for ensuring that our future administrators, whether in Government or industry, have some knowledge of its methods and possibilities. Neither in teachers' training colleges, the public or secondary schools, nor all the universities, is there an adequate appreciation of the universality of science in the modern world. The solution cannot be discussed here, but calls for earnest attention.

41. The Norwood Committee on secondary school curriculum has stated, Neither in teachers' training colleges, the public or secondary schools, nor all the first stage the course in all schools and for all pupils should consist of a general approach to the main fields of Natural science. . . . Degree courses comprising several subjects of Natural science should become more common and be more commonly taken in universities in order to increase the number of teachers." We welcome these views and hope they will be put into practice. It is equally important that the science graduate should have a good general education and we support the further recommendation of the Norwood Committee that "A pronouncement, conceived and expressed on broad lines, should indicate the qualities of mind and character, the general and particular training which it is desired to see in students undertaking university studies in the various fields of natural science."

42. There is a further point. A Report issued by the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research as far back as 1916 (Cd. 8336) states, "Effective research particularly in its industrial application calls increasingly for the support and impetus that comes from the systematised delving of a corps of sappers working intelligently but under orders. . . . Without the scientific rank and file it will be as impossible to staff the industrial research laboratories which are coming, as to fight a European war with seven divisions." There are many men of this type, some of high intelligence within their own particular compass, for whom systematic training should be provided, but for whom a university course is impractical, inappropriate or uncongenial. It is possible that the solution of the problem may be found in the reorganisation and improvement of our technical colleges. There are some, even now, offering the necessary facilities. Conversely, there will be a number of those in technical schools and colleges,

and perhaps in the young people's colleges. who reveal an aptitude for scientific work and would benefit from a university education. Special avenues into the universities need to be devised for such men and arrangements made for the scholarships or bursaries required.

43. A related problem, of first importance to the adequate development of our science departments, is the supply and training of laboratory technicians. These may be trained in any laboratory, but the universities or technical colleges are better suited for the purpose. Consideration might be given to the setting up of training schools for technicians and to the awarding of diplomas in laboratory arts.* It is highly desirable not only that these technicians should enjoy a better status and remuneration than, in many cases, they do to-day, but that systematic training courses and time off for study should be a condition of their employment. In the past, far too few laboratory technicians or mechanics have been employed in the average research laboratory in the United Kingdom. Experience in the U.S.A. and elsewhere shows that one graduate research worker can, on the average, usefully employ at least three laboratory technicians.

44. A great expansion in technical education was planned before the war, and is now more than ever necessary. As indicated in paragraphs 80 and 83 of the White Paper on Educational Reconstruction: "Plans were in hand immediately before the war to increase the provision of technical, commercial, and art colleges, and to expand and bring up-to-date, where necessary, those already in existence. For this purpose a programme of capital expenditure of some £12,000,000 was contemplated. The post-war cost of such a programme will inevitably be higher, but it will be of the first importance that these plans should be revised and expanded to meet new requirements, and, as soon as possible, carried into effect. Provision will accordingly be made to place a duty on Education Authorities to provide adequate facilities for technical, commercial and art education both full-time and part-time," and also "During the war the technical colleges have made a contribution to the specialised training of the personnel required in various departments of the war effort, the value of which cannot easily be overrated. Given the opportunity, they have shown—notwithstanding the handicaps imposed by war conditions—that they can assist in effective training to a degree and in a way, the possibilities of which industry has not hitherto generally appreciated. What is wanted, if the full value is to be obtained from the developments envisaged is that industry and commerce should review their arrangements for training, and should co-operate in associating the technical colleges and art schools more fully with the industrial and commercial life of the country." We cordially welcome these assurances from the Government and hope there will be no delay in putting them into practice.

45. The question of the respective functions of the universities and technical institutions equally needs careful consideration, if both are to play their appropriate part in the higher education of scientists and technicians. As a useful step towards the solution the Board of Education, which bears the responsibility for technical education, should arrange consultations to include the University Grants Committee and the Vice-Chancellors of the universities. Consideration should also be given to the possibility of making more colleges into institutes of technology on American lines, with much more full-time work and chairs in various branches of applied science (as in the Royal College of Technology, Glasgow, and the Manchester College of Technology). It is in such places as well as the universities, that the urgently needed chairs of aeronautics, radio engineering and so on, might be founded. In this connection the recent statement of Lord Cherwell in the House of Lords on July 13th should be noted as to the possible founding of a school of aeronautical

* The Institute of Physics does award a Diploma in Laboratory Arts; there are very few candidates, owing to lack of pressure by employers and lack of teaching facilities.

science.* It is hoped that in this connection an early decision will be reached and the necessary action taken.

46. Finally, there should be larger assistance to young people in industry to enable them to take full-time courses. The proposals in the White Paper on Educational Reconstruction for compulsory part-time education up to 18 are most welcome but are not in themselves sufficient to provide the number of first-class technologists which this country will need. The enthusiasm needed to keep up study one day a week for many years for an examination which others can take after less than one year's full-time study is rarely met with. Some 80 per cent. of those who have in the past taken up part-time courses have not fully completed them. For the production of an adequate supply of technologists the country would need more almost full-time education of a limited number of highly selected young people. Only in this way shall we be able to produce the men who have a fundamental understanding of processes as well as those who know how to work the levers and supervise the repairs. By this means also the level and volume of research in technology could be raised in a comparatively short time.

47. These problems, and the urgent one of the supply and training of technical teachers, should form the subject of early enquiry. The amount of natural ability in search of training is very great. One of our major national resources is awaiting full development once we realise that it is now a matter of training technologists rather than technicians. The universities and their research departments hold the key position in this matter. The devoted and unsparing efforts of our university professors to keep the flag of research and higher education flying high in Great Britain despite the pressure of other duties and inadequate financial resources and equipment deserves high praise. Far greater resources must, however, be placed at their disposal if they are adequately to fulfil their vital function in the new age into which we are moving. Such expenditure should be an essential investment of high priority in the post-war world, yielding in the long term a much higher return than in any alternative field.

48. Professor A. V. Hill, M.P., recently wrote.—"Let us aim high in these matters from the start. Let us aim to double or treble the number of students who are given a higher education in science and technology; let us raise the standard of entry, by accepting only the best students regardless of private means; let us raise the quality of their education by improvement in accommodation, equipment and teaching. The final result may then be the five-to-ten-fold improvement and increase of scientific and technical education which the technical needs of our future will require."

NOTE I.—It is the intention of the Parliamentary and Scientific Committee to return in a future report to the general question of how research in Great Britain may be developed and organised in the most efficient manner. In this document, the Committee assumes that the need for all-round expansion is agreed and addresses itself particularly to the urgent problem of ensuring the supply of the necessary personnel.

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* . . "The Government have asked the Aeronautical Research Committee to explore the possibility of founding a school of aeronautical science. . . The details will have to be worked out—whether students should enter directly from school or whether they should be recruited from the universities after passing some preliminary examination in the fundamental sciences; the conditions of entry for post-graduate students; the relations with existing research institutions, and so on. . . . Such an institution, however, could not be a substitute for our great existing research centres such as the National Physical Laboratory and the Royal Aircraft Establishment, but it could, and indeed it must, carry on research.

Great laboratories will be required for all aeronautic and ancillary subjects, and it is most desirable that this institution should be close enough to one of the great existing research centres for students to be associated with work requiring the most elaborate equipment in the country. The school should, of course, be as free from bureaucratic control as are the universities, and the teaching staff must have the same freedom as in a university. For all this it is clear that a considerable subvention from the Treasury is required. These schemes are still at the exploratory stage; financial and other considerations have still to be taken into account."

NOTE II.—"Research" in this paper refers only to Scientific and Technological research, but this should *not* be taken to mean that in the opinion of this Committee, other forms of research can be overlooked or forgotten.

SUMMARY OF PROPOSALS

1. If Britain is to maintain her position in the post-war world and carry out her plans for reconstruction and social betterment, scientific research and the application of scientific knowledge should be promoted on a far bolder and more imaginative scale than in 1919—39. This applies equally to fundamental, industrial, agricultural, veterinary, medical, and other allied research.

2. There should accordingly be proportional expansion of the supply of scientific personnel.

3. This in turn calls for expansion at the universities, and technical colleges, and an all-round improvement in the teaching of science and scientific principles at all stages of education for the whole school population of the country.

4. As a first step there should be an effective organisation of the demobilisation of the large number of scientific people now on war work or in the Services to enable them to complete their training and to guide them into positions where their previous training and their war experience will be of special value. It is hoped that this will be adequately covered by the Committees under Lord Hankey, but the maximum assistance will be required from Government and private enterprise.

5. The universities should prepare for a rapid growth in the number of students of science and technology. This will call for an expansion of existing universities, and possibly the development of some existing establishments into new universities.

6. State Bursaries and Engineering Cadetships should be continued after the war is over and developed to cover sciences not hitherto included, and the recommendations of the Norwood Committee on this point generously implemented.

7. Materials and finance should be made available for the expansion of research schools in the universities. The number and value and scope of the post-graduate grants awarded by the D.S.I.R. also need to be considerably increased; more post-doctoral fellowships are also required.

8. University staffs, stipends and buildings should all be increased. A capital sum of £10,000,000 will be required for buildings and equipment spread over the first five post-war years, as well as adequate priority for the work and materials involved.

9. The present annual Treasury grant to the universities of approximately £2¼ millions p. a. should be increased to £6 or £7 millions p. a.

10. The freedom, independence and diversity of the universities should not be prejudiced in any circumstances, but to ensure the best use of the increased funds, and to avoid wasteful overlapping, they should set up a suitable Universities' Advisory Council.

11. The recent assurance of the Government that they recognise the need for increasing the provision for technical education is most welcome and it is hoped that this proposal for a revision and expansion of the £12,000,000 scheme of development mooted before the war will be put into effect without delay. The provision of adequate facilities for part-time technical study and training should also be increased.

12. There is a need for greater assistance to promising young people already engaged in industry to enable them to take full or part-time courses.

13. Courses in "laboratory arts" should be instituted in order that there shall be an adequate supply of properly trained laboratory technicians, and young people should be encouraged by the provision of grants to enrol in such courses. The status and remuneration of laboratory technicians require improvement.

14. The supply and training of technical teachers require urgent investigation.

15. There should be a considerable increase in the Parliamentary Grants-in-Aid to the Royal Society for Scientific Investigations and Publications.

October, 1943.

III. INDUSTRY AND EDUCATION

Nuffield College,
17, Banbury Road, Oxford.
January, 1943.

THE STATEMENT contained in this pamphlet is the outcome of a private conference held in Oxford under the auspices of Nuffield College on 26 and 27 September 1942, and embodies the broad conclusions then reached. The detailed drafting has necessarily been the work of a few, and we do not hold ourselves committed to it in every detail. We do, however, strongly support the general tenor of its recommendations, and associate ourselves with its underlying attitude. Signing purely in our personal capacities, we offer it as a contribution to an aspect of educational policy which is commonly much too little stressed, but is of vital importance both for the future economic prosperity of Great Britain and for the well-being and happiness of its citizens.

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A STATEMENT

The relations between industry and education are of fundamental importance to the planning of our life as a nation; and it is essential to plan harmoniously for both. This war has already brought with it changes in the structure and working of industry, above all on the human side, much further-reaching than those which developed during the last war; and, on the side of education, plans are being laid for extensive developments which must, if they are to produce the benefits expected of them, pay due regard to the needs of industry. This does not mean that the representatives of industry should seek, in the name of economy, to set narrow bounds to the ambitions of the representatives of education, but rather that, to the extent to which their respective needs can be met and harmonized, Great Britain can look forward with confidence to a coming period of rapid advance in both industry and education.

The Need for Cheap and Efficient Production

In approaching the common problems of both groups, it is necessary to stress certain inescapable facts. On the economic side, Great Britain can emerge from the present war with hope of steady and speedy advancement in wealth and welfare to the extent, and only to the extent, that British industry is able to produce efficiently and cheaply a wide range of goods for consumption overseas as well as at home. This necessity is plainly involved in the dependence of Great Britain on large-scale imports of both foodstuffs and raw materials, which will have to be paid for mainly by exports of British manufactured goods. This need will exist, however, successful we may be in improving the efficiency of British agriculture; and it involves that all plans for advancing the standards of living of the British people must depend, in the last resort, on the efficiency of British production and on the ability of British industry to sell goods in the world market at prices which overseas purchasers are prepared and able to pay.

The Case Against 'Cheap' Labour

In the past, insistence on the need for cheap production has often led industrialists to lay stress on the necessity of maintaining a supply of 'cheap' labour, and even to oppose any development the social services which has seemed to threaten, directly or indirectly, the laying of additional costs on the producers. It is, however, sufficiently apparent that in this country the quest for 'cheap' labour, measured exclusively in terms of low money rates of wages, is bound to end in failure; and it is now generally admitted that labour which is badly paid is by no means necessarily cheap in terms of real cost. What should interest the industrialist is the productivity of labour in relation to earnings, not the earnings as such; and as soon as the question is considered from this standpoint it becomes plain that the vital factors, in such a country as ours, are the quality of the labour and the attitude towards production of the individuals who comprise the labour force, at all levels and in all grades. If labour is either inferior in productive quality or reluctant for any reason to give of its best, Great Britain's prospect of maintaining a high standard of living is poor indeed; for in a contest in terms of poor or reluctant labour what chance have we of regaining or of holding a satisfactory position in the world's markets, or of playing the part we ought to play in the great tasks of world development which lie ahead?

The Changing Age-Structure and its Moral

Emphasis must therefore be laid above all on improving the quality of labour and on ensuring an attitude to production which will inspire all those concerned with industry to endeavour to raise productivity to the highest possible level. Moreover, this requirement is powerfully reinforced by the prospective age-structure of the British people. Even if existing trends are substantially modified, as we hope they will be, nothing can now prevent the post-war population of Great Britain from including for some time to come a much higher proportion of elderly workers and a much smaller proportion of juveniles than at any previous period. Some will doubtless argue that a time when there is a growing natural scarcity of juvenile labour is the worst possible time for increasing the public provision for education, and this withdrawing a larger number of juveniles from the labour market. Our conclusion is entirely opposite; we hold that the scarcity of boys and girls imposes upon us as a nation the imperative obligation to improve their quality, both as producers and as citizens, to the highest possible point, and we are convinced that this cannot be done without a great extension of the public provision for education, of the right kinds, or without a changed attitude both of educationists to industry and, to at least an equal extent, of industrialists to education.

I. THREE GROUPS OF ENTRANTS TO INDUSTRY

From the standpoint of industry, it is necessary to take account of three main streams of recruits which at present flow out from the educational system to productive occupations. The first of these groups, and by far the largest, consists of those who leave school at the statutory leaving age, and pick up any further education outside working hours, save to the extent to which employers release them for day-time study. The second group consists of those who remain at a secondary or technical school for some time beyond the statutory leaving age, and thereafter enter industry without proceeding to full-time courses either at a University or at a Technical College. The third and smallest group consists of those who enter industry either immediately after a full-time University or higher Technical course, or after a further period of full-time study or research following such a course. These three groups are not perfectly distinct, nor do they include quite all the entrants to industry; but they are at present distinct and inclusive enough to provide a clue to the main problems which have to be faced.

The Problem of Opportunity

We do not mean to suggest that the relations between these three groups will remain permanently what they are to-day. Indeed, if our suggestions are adopted, one of their effects will be to modify the relations which exist at

present between the groups, both by making it more certain than it is to-day, that the really able man will be able to get the full benefits of higher education, and by broadening the highway by which those who enter industry at the lower levels may advance even to the highest positions. It is of the greatest importance to ensure that no brains or skill are wasted either by the premature termination of the educational process in the case of those who show early promise, or, when the entry to industry is made early, by the denial of adequate opportunities for higher education to those whose subsequent mental development shows their capacity to profit by it. The provision made for the improved preparation and training of those who come to industry from the higher levels of the educational system must on no account be allowed to block the road to promotion to the earlier entrants. On the contrary, improved facilities for continued education at every stage must make it much easier than it is to-day for the 'late developer' or the man who for any reason has had his education cut short to make his way to the highest forms of service he is capable of rendering.

What Industry asks of the common school

First let us consider the position of those who enter industry at the statutory leaving age. What does industry require of them; and what have they a right to require of industry? Industry should not require of them that they shall have received at school any specific vocational preparation for the occupations which they are about to enter; and there can be no greater misunderstanding of the real needs of industry than to suppose that it should. The demand which industry should make of these entrants is that they shall be as intelligent and as adaptable as is possible in both hand and mind—that, and nothing else than that they shall be inspired with a zeal to give of their best and with a creative and forward-looking spirit. Industry itself can best undertake the specific training of such entrants, or collaborate with educational agencies in providing for it after they have left school. It is altogether the wrong course to attempt to turn the common school into a place of specialized trade training for those who are to enter industry at the statutory leaving age.

The Basic Provision of Education

In saying this, we are assuming that the post-war leaving age will be 15 at least, without statutory exemptions; and we are also agreed that the leaving age should be raised to 16 as soon as it is practicable to ensure a satisfactory provision of teaching staffs and equipment. We are, however, of the opinion that it is fully as urgent a matter to improve the quality of education up to the age of 15, and to make provision for continued part-time education beyond that age, as to raise the statutory age to 16. We take this view particularly because we are convinced that the standards of primary education for the younger age groups have been allowed to lag dangerously behind recent advances in the senior branches of elementary education, and that the continuance of large classes, obsolete buildings, inferior equipment, and low standards of teaching in primary schools puts fatal obstacles in the way of a right use of the later years of compulsory education. We are firmly convinced that the complete cessation of formal education, for the great majority, at the statutory leaving age is largely responsible for stultifying the efforts of those who are endeavouring to improve the standards and extend the range of voluntary education among both adolescents and adults.

Junior Technical Schools

Our insistence on the need for a non-vocational curriculum up to the statutory leaving age is not meant to exclude attendance at Junior Technical Schools, of which, on the contrary, we look forward to a very great development. The curriculum of such schools should not be (nor is it always in fact) vocational to a greater degree than other forms of general education. It is of cardinal importance that the main aim of the Junior Technical Schools should be to give a wide instruction in mathematics and basic science and also to continue the education of their students in general and social subjects, rather than to teach the technique of any particular occupation or craft. In particular, no less attention should be paid in such schools than in any others to the speaking and

writing of good and exact English and to the giving of a clear understanding of the essential character and institutions of the society in which the students will be called on to play their part. These things, in the Junior Technical Schools as elsewhere, should be taught not merely as separate 'subjects', but as an integral part of the whole course, and should permeate the teaching of all subjects.

Specialided 'Trade Schools'

We do not desire wholly to rule out what is called the 'Trade School', specialized to a particular range of occupations, provided that this range is wide enough and the character of the occupations included in it suitable to give the school an essentially non-vocational curriculum, and further that the curriculum is conceived in the spirit which we have recommended for the Junior Technical School, and retains its broadly cultural character. We are, however, of opinion that in general, for those entering at 13 or 14 years of age, the Technical School is much to be preferred to the more specialized 'Trade School', except in areas dominated by particular types of industry calling for a different basic educational preparation; and we hold that such exceptions should be admitted only after careful scrutiny. We are not dealing in the present Statement with the problems of agricultural education, or we should, of course, stress the need for giving careful consideration to the types of curricula suitable for schools in predominantly rural areas, and to the importance of making fuller provision for specialized higher education for agricultural pursuits.

A good general education indispensable

In effect, our view is that all normal children who are expected to leave school at the statutory leaving age should follow, up to that age, a broadly non-vocational course, either in a senior or secondary school or in a technical school, and that the learning of any specific trade should be postponed until, by these means, a satisfactory groundwork of general education has been laid. It follows that, whereas in the Technical School there will be a curriculum centring upon basic mathematics and science, but also paying due attention to English and to social subjects, in the senior or secondary school that is not primarily technical the teaching of cultural subjects will be combined with an attempt to give every pupil a sufficient grounding in elementary mathematics and in the foundations of science.

The need to provide for easy transfer

One reason for insistence on this basic similarity of courses up to the statutory leaving age is that, in order to avoid premature decision of a child's future, it should be made as easy as possible to transfer from one type of school to another after the age at which transfer will normally take place from the primary to the senior or secondary school. The provision for such transfers should be elastic enough to make movement as easy to or from Grammar or secondary schools at which it is normal for children to remain beyond the statutory leaving age as to or from schools which children normally leave at that age. It is exceedingly undesirable, in view of the great differences between early and late developers, to set up any system so rigid as to make early decisions about a child's future education irrevocable, even if they are seen to have been wrong. It is, of course, indispensable that, in the planning of the alternative forms of higher education, there shall be a complete acceptance of the principle of common standards for all types of secondary school; for without this transfers cannot work effectively, and a stigma of social inferiority will continue to cling to Technical and Modern Schools as against the Grammar Schools to which alone the requisite 'secondary' standards of staffing and equipment have hitherto been applied.

Compulsory Continued Education

We are writing under the assumption that it is intended after the war to introduce a system of compulsory part-time education for all boys and girls between the statutory leaving age and 18, and that, even if this development of adolescent education has to begin on a relatively modest scale, it will be

extended as rapidly as possible to the point at which the working time of young persons is divided with approximate equality between education and employment. This raises two main questions—the character of the curriculum that is to be followed in Day Continuation Schools, and the relation between day continued education and Works Schools or other forms of education given under industrial auspices or from a predominantly vocational standpoint.

The Continuation School Curriculum

It is our view that, at all events for as long as the State provision of day-time continued education does not exceed one and a half days a week, the curriculum of Day Continuation Schools shall be non-vocational, in the same sense as we have used the term in speaking of Junior Technical Schools. The aim of the Day Continuation School should be to continue the adolescent's general (including mathematical and scientific) education, and not to teach the processes of a particular trade. To the extent that vocational trade teaching is provided, it should be done either in the works, where a special Training School is often highly desirable, or in a Technical School kept distinct from the Day Continuation School, even if it forms part of the same group of buildings. This does not exclude either the introduction of trade courses into the Continuation School curriculum when the total provision exceeds a day and a half per week, or the seconding of those over 16 for part of their time from the Day Continuation School for attendance at more specialized trade courses. But it must be clearly understood that the main purpose of day-time continued education is not vocational, but an extension of general education beyond the statutory leaving age and the provision of a much-needed bridge between school and adult education.

The Part of Industry in Vocational Training

It follows from this conception of continued education that industry must itself assume the responsibility of providing, or facilitating, such vocational training as it requires of those who enter its service at the statutory leaving age. This has a different bearing upon those who are proposing to enter a skilled craft by way of apprenticeship and upon those whose jobs in industry do not call for a prolonged period of training. In general, it is undesirable for trade apprenticeships to begin before 16, or for those entering upon them—or indeed for anyone at all—to leave off full-time schooling before that age. It is especially undesirable for a period before the beginning of apprenticeship to be spent in a blind-alley occupation. Provision should therefore be made for prospective apprentices to remain at a secondary or technical school until 16, and the requisite scholarships and maintenance grants for this purpose should be made available pending a general raising of the statutory leaving age to 16. This, however, should not prevent those who, having left school earlier, show their suitability for apprenticeship to a skilled craft, from being admitted as apprentices and in such cases it may well be necessary to provide for special day release in order to enable such entrants to improve their basic education.

Remove the bias against manual occupations

In this connexion, we wish to stress the need for doing everything possible to raise the quality of entrants to apprenticeship in the skilled manual crafts. The bias of the educational system has been recently to a growing extent against entry to manual occupations, and in favour of directing the boys who are above the average intelligence into non-manual work. We protest against this except where the non-manual occupations are such as to call for a high degree of intelligence; but to the extent to which it is the result of a supposed prestige of non-manual work, even of a relatively unskilled kind, we believe the results to be most unfortunate. It is of the greatest importance to raise the prestige of high manual skill, and to persuade boys, parents, and schoolmasters alike that the skilled crafts offer at least as promising and interesting a prospect, and as good an opportunity of advancement, as many 'white-collar' jobs. Unless those who hold the key positions can be convinced of this truth, and persuaded to act upon

it, the development of industry is bound to be seriously prejudiced and productivity to remain at too low a level to satisfy the reasonable aspirations of the main body of the people.

The Essentials of Apprentice Training

Apprenticeship, in our view, should rest on a foundation of all-round workshop training combined with specialized trade education. It is disastrous to use apprentices as a source of cheap labour, and essential to provide for their release for specific trade education over and above the State provision in the Day Continuation School. It is highly desirable that all employers taking apprentices shall so arrange that a full half of their work-time up to 18 shall be devoted to education, including vocational education, and that, after 18, they shall be given every possible facility for attendance at higher courses and for preparation for vocational examinations, such as the Higher National Certificates. We by no means accept the view that apprenticeship is obsolete, or in process of becoming so. On the contrary, we believe that in many industries the need for highly trained craftsmen is increasing, and certain to increase, and that even where the proportion of skilled workers in the total labour force is declining, the degree of skill required of the craftsmen is becoming definitely higher and more exacting; and we strongly urge in all appropriate industries the establishment of agreed National Apprenticeship Schemes under which the industry as a whole will accept responsibility for the training and welfare of apprentices, and for the necessary release to enable them to maintain their day-time studies.

The Shortcomings of the 'Night School' System

We urge this the more strongly because we are convinced that the existing practice, whereby most apprentices and other young workers have to get their higher technical education by attendance at evening courses after a full day's work, imposes an undue and illegitimate strain upon the adolescent. This is seen, not only in the high percentage who fail to finish the courses upon which they have set out, but also among those who do finish their courses, in an impoverishment of initiative and intellectual quality at a period of life critical for the full development of the powers and capacities of the individual. We are not denying the value of the evening school; indeed, we regard it as an indispensable part of the provision for technical education over a wide field. But we are convinced that a considerable element of day-time release is necessary in order to enable those who embark on part-time technical education to have a reasonable chance of deriving full profit from it; and we urge that evening attendance should be regarded rather as a means of finding out which aspirants are worthy of being given fuller opportunities than as in itself a satisfactory means of enabling young men of promise to achieve the qualifications needed by them or the mental development of which they are capable, given the right conditions.

Training for less skilled occupations.

For those who enter industry at the statutory leaving age, not as prospective craftsmen, but for less skilled work, or for work requiring only short periods of specialized training, we hold that in general such training as is needed can best be provided in the works, but that where such young workers show signs of special ability, either in relation to their jobs or in any other field, employers should be prepared to grant them, over and above compulsory attendance at the Day Continuation School, periods of day-time release for further study, according to their several bents, including cultural study which bears no specific relation to their daily work, on terms not less generous than would be accorded to apprentices for studies connected with their craft training.

Wider cultural opportunities for the repetition worker

The basis for this suggestion is that, in order to secure a contented labour force of high productive and personal quality, it is essential to do everything possible to avoid a sense of thwartedness developing among those who have no prospect of rising through craftsmanship and higher vocational training in their specific jobs. This requires the widest possible opening of the opportunities for higher cultural education during the years of adolescence; for if the chance is

missed then, it is very much harder for most persons to profit by the opportunities for cultural development through adult education at a later stage.

The dual road to development

It is, in effect, necessary to ensure as far as possible for every young worker a dual road to self-development, by broadening the avenues for advancement through industry itself, and at the same time offering to those who do not travel on by this route the fullest practicable chance of satisfaction and development by the better and more instructed use of leisure. It is no mean part of industry's responsibility to those whom it employs to ensure that both these ways of human progress shall be made broad and easy of access to all comers.

II.—THE SECOND GROUP OF ENTRANTS

We can now turn to the problems which affect those entrants to industry who remain in full-time education past the statutory leaving age, but do not proceed from school to a full-time degree course in a University, or to an analogous higher full-time course in a Technical College. This group is a good deal more heterogeneous than the much larger group which we have been so far discussing, for it includes young persons leaving school at varying ages, from about 16 to 19. It should be made clear that we are not, in this document, dealing at all with the problems of commercial education, or with those entering commerce or primarily commercial jobs. Nor are we dealing with agricultural education. To attempt to cover these fields, important as they are, would involve entering into a host of questions which were not before us when the groundwork of this document was being prepared; and we do not propose to enter upon these questions now. We are dealing with entrants to industry proper, and not to commerce or agriculture—and by this we mean that we are considering only such jobs as call for manual dexterity or craftsmanship, or for technical or scientific, as distinct from primarily commercial, attainments.

The Second Group Defined

When boys remain at school until about 16, and then enter directly upon manual apprenticeship leading to a skilled craft, no new problem arises; and what we have to say has been said already under a previous head. We are here considering rather those entrants from the higher forms of secondary or public schools, or from Senior Technical Schools, who enter industry in order to become, not manual workers, but members of the technical or research or administrative staffs of industry. It is to be noticed in this connexion that boys from the better-known public schools, save where they directly enter family businesses, have hitherto played only a small part in the recruitment of industry at this stage. The main recruitment has been from the State or State-aided Secondary Schools, or from the Higher Technical Schools, where they exist. This is a sign that those who can usually do proceed from the public or Secondary School to the University, or to full-time course in a Technical College; and we are of opinion that this is right, and that it is in the interests of industry to recruit its higher personnel, where it is not promoted from the ranks of the manual workers, largely from University graduates or from those who have been through full-time higher technical courses rather than from those who have left school relatively late without proceeding to a University or its equivalent.

What industry requires of the secondary schools

There will, however, remain a very substantial number who will enter industry direct from the higher forms of a State secondary, or public, or higher technical school—for example, as assistants in scientific laboratories, or as apprentices of a type intermediate between the works apprentice and the graduate entrant of the highest grade. What industry demands of the schools in relation to such entrants is that the school-courses provided for them shall stand on their own merits, and shall not be devised primarily as preparations for University courses which most of those who take them are not in fact likely to pursue. The adolescent who leaves school to enter industry at 17 or 18 should have received, up to the level appropriate to his age, a rounded education, and not part of an education designed for persons whose full-time education is to

continue for some years more. To secure this, it is necessary to release the schools from thraldom to an examination system conceived too much under University influence, or rather from a standpoint which regards the school primarily as a place of preparation for University work. We do not propose to enter into the technicalities of the present system of school and University examinations, as they affect this issue, but only to record our conviction of the necessity of a thorough overhaul.

Over-Specialization at school

The main need of industry, in boys entering it from the higher forms of public or secondary schools, or from higher technical schools, is the broadest and deepest possible development of general intelligence and initiative, and therewith a sound basis of general scientific and mathematical knowledge. Premature specialization, before there has been time for these foundations to be made firm, is as much contrary to the requirements of industry as to the full and balanced growth of the individual. To the extent to which the present tendency towards premature specialization is due to the high degree of specialization in University scholarship examinations, the evil can be removed by planning school courses as complete in themselves, and not as a preparation for University work; but, as we shall see later, the present system is hardly less unfortunate for those who do proceed to a University than for those who do not, and we are convinced that a complete overhaul of University scholarship examinations, as well as of higher school examinations, is imperatively needed.

Opportunities for Higher Education

The question of opportunity is fully as important for the group of entrants to industry now under consideration as for those who enter at an earlier age. Indeed, in one sense it is even more critical; for they are apt to fall between two stools. Expecting to belong to the higher personnel of industry, rather than to the rank and file, they are in general at a disadvantage in comparison with those who enter after a University or similar course. Many of them, in order to get rid of this disadvantage, seek to obtain degrees through external University examinations, or work at Technical Colleges for Higher National Certificates or other advanced diplomas. When they are compelled to do this over and above a full week's work, the strain is often severe. Many fail to finish their courses, and among those who do reach their goal there is often a limited attainment and a lack of personal initiative which make against success in securing promotion to more responsible posts. It is clear that at this stage, as well as at the earlier stages with which we have dealt already, everything possible ought to be done to assist those who are endeavouring to improve their technical qualifications by further study. Release should be made easy, both for daytime attendance at appropriate courses, and for private study; and wherever possible a period of entire release prior to critical examinations should be arranged. Nor should it be overlooked that the advantage of those who have been through a full-time University course is not to be measured solely in terms of the higher specialized knowledge which they have been enabled to acquire, but equally in terms of their wider opportunities for social contacts and for broadening as well as deepening their knowledge. Accordingly, whatever can be done should be done to help this group to improve their cultural and social as well as their technical qualifications for higher and more responsible posts.

The Prospects of Promotion

It is often said that men who set out to improve their prospects by means of external degrees or higher technical qualifications are more apt to be lacking in the qualities of leadership and personality than in other respects. This is a reason for widening their opportunities in the way suggested and also, in many cases, for giving them chances of promotion, not in the establishments in which they have previously held an inferior status, but elsewhere. It is also sometimes argued that it is unwise to open the door too wide to the winning of high paper qualifications, because of the danger that the supply of qualified candidates may greatly exceed the number of higher posts. We agree that this presents a special problem in certain industries—in those which are declining

in total strength and in those which employ few technical workers in relation to their total labour force. But we do not believe that the danger is serious in most industries, on the assumption that the post-war economic system will be generally in an expanding condition, and that what is called 'full employment', or something like it, will be a definite part of national economic policy. In most industries, the proportional employment of the higher specialists should certainly expand rather than contract, as production comes to be more scientifically organized; and there ought to be room for much more promotion, and not for less. We have therefore no hesitation in pressing for a large increase in the facilities for higher technical education, not only for full-time students, but also for those already in industry who follow higher courses in their spare time or, much preferably, with the aid of part-time release.

III.—THE QUESTION OF NATIONAL SERVICE

Before we proceed to consider the position of these recruits to industry who enter gainful employment after a University or equivalent full-time course, it is necessary to deal with a problem which affects educationally both this group and the group of which we have just been speaking. This is the problem of compulsory national service, which is being widely discussed. We are not qualified to say how far such service, if it is introduced, will need in the post-war world to assume a military character, or what part of, say, a year's service at 18 or 19 would have to be taken up by purely military training. But, as industry as well as education would evidently be very much affected by the introduction of a 'national service year', we cannot pass over the matter entirely in silence—the more so because it is very closely connected with another issue on which we hold strong views.

The 'Break'

It is a matter of common agreement among us, whether we are industrialists or educationists, that those boys who proceed from school to a University with the intention or prospect of entering industry subsequently would do better if between their school and University careers there were interposed some sort of 'break'. This has been often suggested in a variety of forms, and on more than one ground. It has been argued that it would be a great advantage for boys meaning to enter industry to get some advance knowledge of industrial methods and processes, and of the human side of industry, before taking their University courses, whether or not these courses are in subjects directly and obviously related to workshop problems. It has also been strongly urged that University work would achieve better human results if, before beginning upon it, boys leaving school had a period free from examinations and devoted largely to practical rather than student affairs. As against this second argument it has been urged that it would be dangerous to have so long a 'break' as to allow youths to get out of the habit of learning; and in reply to this criticism it has been said that it should not be impossible to devise a form of 'break' which would include some continuance of education (without examinations) side by side with a spell of practical work.

A Year's Break Desirable

Our general view is that, if there were no question of compulsory national service, it would be desirable to provide for a year's 'break' between school and University. Some firms already provide for the attendance of prospective employees at their works during the long vacation between leaving school and entering the University, as well as for further vacation attendances during the University period. Further, a few boys leave school before the summer term, and thus get a period of up to six months' workshop training before they proceed to their University course. But these cases are few ,and we are agreed in holding that there are serious obstacles in the way of generalizing such arrangements. We should greatly prefer a 'break' of a full year, including some provision for continued education during this period; and we believe that, apart from the problem of compulsory national service, the full year would be easier to arrange than either a shorter or a longer time.

The use of the 'Service Year'

It is, however, necessary to consider how such a system would fit in with the introduction of a period of compulsory national service, presumably at 18 or at least 19. If this service were wholly or mainly military, the need for a further 'break' on industrial and educational grounds would still remain; but the extension of the total 'break' to as much as two years would increase very greatly the danger that the habit of learning would become undermined before University education could begin, and would have the further disadvantage of pushing on the completion of the University course to too late a time in life. If, however, the need for military training could be met in such a way as to leave room, within the 'national service year', for a substantial element of workshop experience or further education—say, by division into two equal periods of military and civilian service—the industrial and educational requirements of the 'break' could perhaps be met in such a way as not to postpone the opening of the University period for more than a single year, though it might be necessary in that event for school-leaving to take place before the summer term. We do not propose to pursue this problem into further detail, as our main purpose is to emphasize the need for the 'break' and for the use of it, without complete interruption of the educational process, as a means of giving those who intend to enter industry after their University career a preliminary experience of workshop practice and organization and of the human contacts of industry.

National Service and the Second Group of Entrants

The question of the 'national service year has, however, also an evident bearing on the position of those who enter industry direct from the higher forms of secondary or public schools, or from the higher ranges of technical education. Are youths, who are destined speedily to be called out of industry by the claims of national service, to enter it for a brief period before the call comes, or are they to defer their entry until their term of national service is over? There is much to be said for their entering industry, and then having a 'break', not from school but from employment, after they have gained a preliminary experience of industrial conditions. But this must depend on the age at which the period of national service falls; for if it falls as early as 18, it is probably better for them to remain at school up to that age, and to defer their entry to industry until they are 19.

The conditions of entry to Universities and Technical Colleges

Special considerations arise in relation to those who pursue their higher education not at a University but at a Technical College. In the case of University students, we are definitely hostile to any policy which, save under war conditions, puts the age of entry at less than 18 or at 19, after a year of national service; for we consider that the essential quality of University education is apt to be forfeited if a beginning is made at an earlier age. But the conditions for entry to Technical Colleges are not entirely the same; and there is a manifest possibility that the introduction of compulsory national service may cut the Technical College course into fragments for a substantial number of students. This is an additional reason for making the 'year of service', if it comes, not exclusively military, and for enabling those engaged upon it to continue their education by dovetailing Technical College work with their military service. That this is fully practicable is shown by the success of war-time courses for University undergraduates, which combine preparation for military service with regular academic work. Apart from the 'national service year', it does not appear to be practicable to provide for a year's 'break' between leaving school and beginning full-time work at a Technical College.

IV.—THE THIRD GROUP OF ENTRANTS

We can now pass on to the problems of University education, as they affect the supply of the higher personnel of industry and of industrial research. We have already indicated our strong opinion that University scholarship examinations, which set standards over a very wide field, tend at present to be unduly specialized and to encourage premature specialization at school. We urge strongly upon the University authorities the desirability of insisting rather on a firm grounding in mathematics and general science than on a high standard of

specialized knowledge in setting scholarship papers and in awarding scholarships; and we hold that examinations governed by this principle and affording a wide range of options, including purely cultural subjects, are to be preferred to the narrow system at present mainly in vogue. Specialization is of the greatest importance, in the higher ranges of knowledge, when an adequate broad groundwork has been already assured; but it is entirely contrary to the needs of industry to turn out specialists who lack this essential groundwork or are unable, for want of a sufficient cultural background, either to speak or write good English or to appreciate the wider issues of industrial organization and policy, or the place which industry occupies in the community and in the processes of social as well as technological development. Industry looks to those who come to it from the highest rungs of the educational ladder to possess qualities of leadership, initiative, and imagination as well as technical and scientific competence; and these qualities need fostering by a broadly based and imaginative handling of the students during their undergraduate careers.

Curricula at the University

It is no part of our purpose to proceed from these general principles to any discussion of University curricula, beyond observing that we cordially approve the practice of devoting the final year of scientific courses to a period of elementary research under thorough supervision, and that the curriculum for those proposing to enter industry should not be so crowded as to prevent students from spending a part of their vacations in gaining workshop or industrial laboratory experience without being heavily penalized in their University examinations. We are well aware of the temptation to overcrowd the curriculum by the inclusion of additional subjects; but we believe most University authorities to be both alive to the danger of yielding to this temptation and aware of the necessity of leaving room for cultural activities and for the social contacts in which so much of the value of University life consists.

Industry and the Universities

Complaint is often made that the Universities seldom send their best men into industry; and the common retort is that industry is often unappreciative of the University-trained man. To some extent, both complaints are justified; and a part of the explanation of both is that there are too few contacts between the Universities and industry. We suggest that it ought to be a comparatively easy matter to increase these contacts. For example, use might be made of the academically trained staffs of industrial research laboratories and of other qualified men in the service of industry on the production side to give regular courses of lectures to University students; and University teachers and research workers could to a greater extent be seconded for periods of service with the research staffs attached to particular industries. We also hold that it would be a great advantage if more men instead of settling down permanently to academic life, could pass over, at about 30, to a period of service in industrial research, and if the entire movement to and fro between 'pure' and industrial research could be made a good deal easier than it is at present. This is partly a matter of the different salary structures of academic and industrial life; but it should not be a very difficult matter to make the necessary adjustments. Nor should it be difficult to forge much closer links between the Universities and the businesses which look to them for technical and professional recruits, by improving the arrangements for University students to gain useful workshop experience during their period of residence in the University.

Research, 'pure' and 'applied'

In this connexion, we wish to stress the extent to which successful research work, both pure and applied (incidentally, the differences between 'pure' and 'applied' research are often unjustifiably exaggerated), depends on co-operation and the free play of mind on mind. Closer personal contacts between those engaged on scientific research in Universities, in industries, and in government research establishments would bring great benefits to all three groups. Moreover, in industry both research and production staffs would be the better for closer contacts. It is highly desirable to give those engaged on production work

some training in research methods and a period of service in a research laboratory. Similarly, those engaged in research on the staffs of big firms and those working for research associations and similar bodies should be brought into closer touch with one another, and there should be the fullest opportunities for the production staffs of smaller firms to gain direct experience of the methods and aims of the research associations connected with their several industries. In these and other ways the triple partnership of Government, industry, and the Universities in the research field could be made much more fruitful.

The Claim of Industry to its share of the best

In our view, industry has a right to claim a higher proportion of the best men from the Universities than it has been getting in the past. This claim is based on the imperative need to harness scientific knowledge fully to the promotion of higher industrial productivity, if the national standards of living are to be improved. We believe that much could be done to ensure a better flow of scientific brains into industry if the processes of selection were better organized. The services performed by University Appointments Boards, good as they are in many respects, are not enough, and often involve much duplication of effort. We hold that the work done by the Central Register during the war shows the value of which such a body, if it were well conducted, could be under more normal conditions in marrying the supply and the demand in the case of highly trained scientific workers; and we urge that the Central Register shall be kept in being and reconstituted as soon as possible on a permanent basis. At the same time, we believe that the fundamental remedy is to be found, not in any kind of formal register, but in much closer contact between the teaching staffs of Universities and those responsible for the recruitment of the higher personnel of industry; and we should like to see everything possible done to put this contact on a more satisfactory footing.

The future of the Technical Colleges

This brings us to the question of the Technical Colleges. We have already expressed the view that the development of industry is likely to call for a considerable increase in the number and proportion of skilled technicians and research workers, and that this need will exist at all levels from the highest down to the lowest, and will require a great expansion of the provision for all forms of technical education. It is sometimes suggested that the higher forms of technical education ought to be concentrated in the Universities, and that the Technical Colleges ought therefore to be brought into the Universities, shedding in the transition the large amount of more elementary work which is at present carried on within their walls. We dissent strongly from this proposal, in the form in which it is usually advanced, though we have much sympathy with the aims which lie behind it. It is simply not practicable to separate the higher from the less advanced forms of Technical Education, or to bring within the existing Universities the large numbers who need higher technical training of one sort or another.

The idea of a 'People's University'

The real purpose of those who make this suggestion can best be served by making the Technical Colleges and other institutions which suffer from a parallel isolation and incompleteness, into the nuclei of a new type of People's Colleges, equipped both to train students for a wide range of vocations and to play an active part in the widening sphere of Adult Education. The grouping of the Technical College and of other suitable institutions upon a common 'campus', to form a 'People's University', with provision for the easy exchange of teaching staffs and for close common intercourse among all the students, offers by far the best hope of endowing higher technical education with that cultural quality in which it is now too often deficient, and of constituting it a school of personality and leadership as well as of technical skill. It is probable that this change in the character of the Technical Colleges would carry with it a sharper separation between the Technical Colleges and the Junior Technical Schools; but this

separation appears to be already implicit in the proposal to create Technical High Schools as a part of the new provision for universal secondary education.

Lifelong Education.

There is yet another need of industry to which we feel compelled to draw attention, although it opens up issues which, if we were to pursue them to the end, would take us far afield from our main subject. Industry needs, from top to bottom, and in every part of its human structure, the continual refreshment of new ideas. Its leading executives, no less than its managerial and technical personnel and the general body of workers engaged in it, need to be kept continually fresh in mind by mixing and meeting with others who can bring to them the invigorating air of different experiences and a different way of approach. To some extent, we have already insisted on this need in what we have said about the importance of adult education. But adult education, as it is understood to-day, does not cover nearly the whole of what we have in mind. It does not cover the need for making regular and systematic provision of 'refresher' courses for managers and technicians, especially for men in the thirties who are at that critical stage in their careers and in their mental development at which a chance to liven up their thinking by getting wider contacts may make all the difference. Nor does it cover the need of those already in high executive positions to broaden and deepen their outlook by contact with what is best in contemporary cultural and scientific thought. We believe that both these needs ought to be met—the first by the establishment of regular courses in management and in social and economic problems suitable for men who can be spared for a few months, or perhaps for a full year, from the businesses in which they have shown promise of high achievement, and the second by providing 'refresher' courses of a wider, cultural character for men who, having already made their mark in the business world, are yet conscious of the call to improve their understanding of the greater issues of contemporary life and thought. We should wish to see both these needs borne in mind in the future development of the Universities and of Adult Education in its broadest and deepest sense, in which it takes its rightful place in society as the instrument of a concept of Lifelong Education open to every human being who cares and is able to profit by it.

V.—THE CONDITIONS OF SUCCESS.

In the foregoing brief review of a number of aspects of the relations between industry and education we have made no pretence either of covering all the ground or of dealing with any matter save in the broadest outline. We are putting forward suggestions, and not a considered scheme: and our aim has been to provoke discussion, and to test the degree of agreement which exists among our colleagues in industry, in the Universities and Technical Colleges, and in other walks of life. There are only two general points which we desire to add to what has been said—points which we put last for the sake of emphasis and because they condition all that has been written on earlier pages.

The case for a wider adult Education Movement

The first of these two points is that we are concerned at least as much with the quality, well-being, and happiness of the main body of the manual workers in industry as with the condition of those who fill the higher positions in its service. No success in recruiting a skilled and intelligent body of men for the higher posts will avail us unless at the same time everything possible is done to achieve the best possible quality in the 'rank and file'. This applies not only to the skilled craftsmen, but equally to the less skilled workers and to those who are engaged upon repetition jobs. It is simply untrue that the less skilled work is best done by unintelligent persons, or that the ideal of industry for such jobs is the 'robot'. Jobs that do not call for intelligence as well as jobs that do call for it are being transferred increasingly from the man to the machine, and will be so transferred to a much greater extent in the near future. Attention is too often concentrated on the latter type of change: so that the effects of changes of the former type are overlooked. In general, we believe that industry

will need not less but more intelligence and adaptability as mechanization makes further advances. It is, however, the case that the workers who are employed upon the less skilled types of work, though they will need to use their intelligence and adaptability in their work, can by no means be expected to find in it a satisfying outlet for their mental qualities. That is one reason why it is necessary, side by side with the improvement of school education, to make ever-increasing and better provision for Adult Education in all its variety, and to give the fullest possible opportunity for that 'Lifelong Education' which is the final objective of the adult education movement.

The need for hope.

Our second—and final—point is this. Men work better, and live more happily, when they work and live in hope. No small part of the reason for the slowness of British industry in seizing its opportunities in recent years and for its comparative failure to strike out, save here and there, along new lines based on the most recent developments of science, has been its lack of faith in the future. Similarly, no small part of the human difficulties, and of the labour difficulties in particular, that have beset industry has come from the same source. The promising young workman who can feel sure that his labour is wanted and that he will be given a chance of proving his fitness for responsibility and for higher forms of service, has far more powerful incentives to give of his best than can be afforded by any system of piecework or bonus inducements, or by any workshop discipline. To most workmen and to many technicians the supreme discouragement to the development and display of the higher faculties is the fear of unemployment—above all when this fear presents itself, as it has done so largely for a generation past, not as a penalty for slackness or inefficiency, but as a sheer calamity, continually threatening good and bad workmen alike because of the defective working of the economic system itself. Not one of the suggestions we have put forward will bear its full fruit unless this inhibiting terror can be exorcized. In order to get an efficiently staffed industry, aiming with all its forces at the highest possible productivity, we must have a forward-looking industry, armed with confidence in the future, and assured that it will not be made the sport either of defective financial arrangements or of official timidity in facing fundamental economic problems. It is often said that industry will be fruitful in proportion as those who are engaged in it are animated by the spirit of service, and regard themselves as the servitors of spiritual and not of merely material values. We endorse this judgment, and we believe the clue to the revival of this sense of spiritual values in industry and in the whole community to be found, in the economic sphere, above all else in removing from men's eyes the spectre of unemployment, and in making plain to all that Government, employers, and workers intend to labour in common for the highest possible productivity, letting no vested interest, of any sort, stand in the way and with a firm determination to make full use of the increased product for the single purpose of enlarging the quality of human life.

SUMMARY OF CONCLUSIONS

1. That it is of fundamental importance to establish the right relations between industry and education and that, in the belief of the signatories, this can be done by harmonizing their respective needs without setting narrow bounds to the ambitions of educational reformers.

2. That, in view of the economic situation in which Great Britain will find itself at the end of the war, it is indispensable to increase the efficiency of British production to the utmost, but that any attempt to re-establish British industry in world markets on the basis of low-wage competition is bound to end in failure. That, accordingly, the quality of labour and the attitude towards production of the individuals who comprise the labour force are the vital factors in raising productivity to a satisfactory level.

3. That the changing age structure of the British population, which involves an increasing scarcity of juvenile labour, so far from being a reason for curtailment of educational opportunities, imposes upon the nation an imperative

obligation to improve the quality of its juveniles, both as producers and as citizens, to the fullest possible extent, and that this involves a great extension of the public provision for education.

4. That the problems of education in its relation to industry need to be considered in relation to the three main streams of recruits who at present flow out from the educational system to productive occupations. These groups are as follows: The first, and by far the largest, consists of those who leave school at the statutory leaving age: the second, of those who remain at school beyond this age but do not proceed to full-time courses at a University or Technical College: and the third, and smallest, of those who enter industry either directly from a degree or higher technical course or after a further period of research following upon such a course.

5. That these three groups are not to be regarded as entirely distinct, and that, to the extent to which they remain distinct, it is of the greatest importance to ensure that there shall be the fullest possible opportunities for promotion from one grade to another, including opportunities for those who enter industry at a relatively early age to receive higher education to the fullest extent of their capacity to profit by it.

6. That, in the case of those who leave school at the statutory age, the main demand of industry is not that they shall have received at school any specific vocational preparation for the occupations which they are about to enter, but rather that they shall be as intelligent and as adaptable as possible, and further that they shall be inspired with a zeal to give of their best and with a creative and forward-looking spirit.

7. That the school-leaving age should be raised to 15 at least, without exemptions, immediately after the war and, as soon as practicable, to 16, but that it is fully as urgent to improve the quality of education at the earlier stages and to make provision for continued part-time education beyond the school-leaving age as to raise the statutory age to 16.

8. That there should be a rapid development of Junior Technical Schools, but that the curriculum of such schools should not be narrowly vocational to any greater degree than that of other schools, but should be such as to provide a wide instruction in mathematics and basic science, and also to continue education in general and social subjects rather than to teach the technique of any particular occupations.

9. That in all schools including Junior Technical Schools, the greatest attention should be paid to the speaking and writing of good and exact English and to the giving of a clear understanding of the essential character and institutions of the society in which the students will have to play their part.

10. That, in general, Technical Schools are much to be preferred to specialised 'Trade Schools', though this should not exclude a bias towards particular groups of trades in areas dominated by particular types of occupation.

11. That all normal children who are expected to leave school at the statutory age should follow up to that age a broadly non-vocational course, and that the learning of any specific trade should be postponed until a satisfactory groundwork of general education has been laid.

12. That it should be made as easy as possible for pupils to transfer from one type of school to another in accordance with their individual capacities and requirements.

13. That it is indispensable, in the planning of alternative forms of higher education, to accept completely the principle of a common standard of provision for all types of secondary school.

14. That a system of compulsory part-time education between the school-leaving age and 18 should be introduced immediately after the war and should be extended as rapidly as possible to the point at which the working time of young persons will be divided with approximate equality between education and employment.

15. That the curriculum of Day Continuation Schools should be primarily designed to continue the adolescent's general education and not to teach the

processes of a particular trade, but that it should include the broad principles of science and technology, and that, as the provision for continued education is increased, some element of trade instruction can reasonably be introduced, provided that the generally non-vocational character of continued education is maintained.

16. That industry itself should assume the main responsibility for providing or facilitating such vocational training as it deems necessary for those who enter its service at the statutory leaving age.

17. That, in general, it is undesirable for trade apprenticeships to begin before 16 or for those entering upon them to leave school before that age, and that accordingly scholarships and maintenance allowances should be made available for this purpose pending a general raising of the leaving age to 16.

18. That all possible steps should be taken to raise the quality of entrants to apprenticeships in the skilled manual crafts and to remove the bias of the educational system against entry to manual occupations. That it is of the greatest importance to raise the prestige of high manual skill and that the development of industry is bound to be seriously prejudiced unless this is done.

19. That apprenticeship should rest on a foundation of all-round workshop training combined with specialized trade education, and that all employers taking apprentices should arrange for half their work-time up to 18 to be devoted to education, including vocational education, and should give every possible facility for those over 18 to attend higher courses and prepare for vocational examinations.

20. That the existing 'night school" system places an undue strain upon the adolescent at a critical period of development and that important as night school education will continue to be, a considerable element of day release is necessary in order to give those who embark on higher technical education a reasonable chance of deriving full profit from it.

21. That for those who enter industry not as craftsmen, but for less skilled work, such training as is needed can in general be best provided in the works, but that employers should be prepared to grant workers of these types periods of day-time release for further study, including cultural study not specifically related to their work, on terms not less generous than would be accorded to apprentices. That this recommendation rests on the view that it is essential to do everything possible to avoid a sense of thwartedness among those who have no prospect of rising through craftsmanship in their specific jobs.

22. That it is essential to provide for every young worker a dual road to self-development, both through advancement in industry itself and by the better use of leisure, and that it is a part of industry's responsibility to those whom it employs to ensure that both these opportunities are made available.

23. That, in the case of those who enter industry at a higher age but without proceeding to a University or equivalent course, it is desirable that the provision made at school shall be complete in itself, and shall not be devised primarily as a preparation for University or other higher courses, and that, in order to ensure this, it is necessary to release the schools from the thraldom to an examination system conceived too much under University influence.

24. That the main requirements of industry from those who enter it from the higher forms of Public or Secondary Schools, or from Higher Technical Schools, are the broadest possible development of general intelligence and initiative, together with a sound basis of general scientific and mathematical knowledge, and that premature specialization is as much contrary to the needs of industry as to the full and balanced growth of the individual.

25. That it is fully as important for entrants from higher education as for those who enter industry at the statutory leaving age to be given the widest possible opportunities for further education, and that this involves a substantial element of release, both for day-time attendance at appropriate courses and for private study.

26. That in view of the probability of an expansion in the demand for the higher specialists in industry, there ought to be a rapid expansion in the facilities for higher technical education, not only for full-time students but also for those already in industry who follow higher courses in their spare time or, preferably, with the aid of part-time release.

27. That it is in the interests both of industry and of the individual that there should be wherever possible a break between leaving school and proceeding to a University or full-time higher technical course, but that this break must not be so long or so complete as to allow youths to get out of the habit of learning.

28. That if there were no question of compulsory national service after the war, it would be desirable to provide for a year's 'break' between school and University, and that a full year would be easier to arrange in many cases than either a shorter or longer period.

29. That, in the event of a system of national service being introduced after the war, the need for a further 'break' on industrial or educational grounds would still remain, but that a total 'break' of two years would be too long. That, accordingly, the length of the 'break' must depend on the period laid down for national service, and also on the character of such service, which might be so arranged as to include a substantial element of workshop experience or further education as well as military service.

30. That, if the period of national service falls as early as 18, it will probably be better for entrants to remain at school up to the period of national service and to defer their entry to industry until after that period, without any period of industrial experience preceding their national service.

31. That nothing should be done to lower the age of entry to Universities below 18, or below 19 if a system of national service at 18 is introduced, but that special considerations arise in relation to the age of entry into Technical Colleges and that the possibilities of dovetailing Technical College work with a period of military service should be explored.

32. That University scholarship examinations tend to be unduly specialized and to encourage premature specialization at school, and that steps should be taken to insist rather on firm grounding in mathematics and general science than on a high standard of special knowledge: further, that stress should be laid on the ability to speak and write good English and to appreciate the wider issues of industrial organization and policy.

33. That the practice of devoting the final year of scientific courses to elementary research under supervision is cordially approved and that University curricula should not be so crowded as to penalize students who would profit by spending a part of their vacations in gaining workshop or industrial laboratory experience.

34. That closer contact should be established between industry and the Universities in order to secure for industry a higher proportion of the abler undergraduates.

35. That closer personal contact should be established between those engaged in scientific research in Universities, industries, and Government research establishments and also, in industry, between research and productive staffs.

36. That, with a view to increasing the proportion of able men entering industry from the Universities, the work of University Appointments Boards should be supplemented by the creation of a reconstituted Central Register on a permanent basis, but that more important than any machinery of this sort is the establishment of closer contracts between the teaching staffs of Universities and those responsible for the recruitment of the higher personnel of industry.

37. That the provision of Technical Colleges should be greatly increased, and all possible steps taken to improve their standards, but that it is not

practicable wholly to separate the higher from the less advanced forms of Technical Education or to bring the Technical Colleges within the Universities. That, accordingly, consideration should be given to the practicability of making the Technical Colleges the nuclei of new types of 'People's Universities', equipped both to train students for a wide range of vocations and to play an active part in the widening sphere of adult education.

38. That the need for education does not cease for any class or grade of persons at any particular age, and that the conception of lifelong education should play an important part in the reconstruction of our educational institutions. That leading executives, no less than managers and technicians and the general body of workers, need to be kept continually fresh in mind by contact with those who can bring them into touch with different experiences and a different way of approach. That this points to the need for a systematic provision both of adult education in its many forms and of refresher courses of many kinds for managers and technicians, including both regular courses in management and wider cultural courses for those who are conscious of the call to improve their understanding of the greater issues of contemporary life and thought.

39. That the growth of mechanization involving repetition work does not, as is often supposed, lower the standards of intelligence required in industry, and that, on the contrary, industry will need not less but more intelligence and adaptability as mechanization advances. That it is, however, true that workers engaged on repetition work cannot be expected to find in it a satisfactory outlet for their mental qualities, and that, accordingly, the need for the widening of cultural opportunities suggested in earlier paragraphs is made all the greater by the development of mass production techniques.

40. That men work better and live more happily when they work and live in hope, and that no small part of the difficulties of industry in recent years have come from the lack of this hope, which has been spread widely by the presence and the pervasive fear of unemployment. That industry will be fruitful in proportion as those engaged in it regard themselves as the servitors of spiritual and not of merely material values, and that the presence of this spirit depends largely on removing from men's minds the spectre of unemployment and in making plain that no vested interest is to be allowed to stand in the way of the fullest possible production, or of the use of full production for the single purpose of improving the quality of human life.

IV. RELATIONSHIP OF RESEARCH ASSOCIATIONS TO THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

(Based on a paper read to the Staff of the British Coal Utilisation Research Association on May 22, 1943).

By A. L. Hetherington, C.B.E.

1. The Department of Scientific and Industrial Research was set up by the Government during the Great War of 1914-18 and one of the first major acts of that Department was to inaugurate a scheme of national research organisations to stand behind and supply with new ideas, new methods, new standards of quality, the principal industries of a nation dependent for its existence on its power to feed itself by means of the sale of its manufactured products. These national research organisations were to be comprised of cooperating firms and called Research Associations, the essential feature of which should be that they were organised by the industry concerned, that industrialists should frame the programmes of work to be followed, and appoint the staffs. In short, the Research Association should be autonomous bodies, controlled by industry but assisted by Government, through the D.S.I.R. It was hoped that the Associations would become self supporting by the date when the original £1,000,000 fund, voted by Parliament for the purpose, was exhausted.

The principle on which this Million Fund was disbursed consisted in implementing offers on the basis of £ for £ for a period of five years on all income raised, on the understanding that a minimum subscription income (placed at much too low a figure as later experience showed) was forthcoming from industrial sources.

2. The Department and its Advisory Council were over optimistic and at the date when the Million Fund became exhausted there was practically no Association at the end of its initial 5 year period showing clear signs of becoming self supporting on an adequate basis. However, an attempt was made to force the pace in fulfilment of the original idea and a scheme of diminishing block grants was devised whereby over a second period of five years the industrial income should be stepped up each year by 20 per cent. jumps and the Department's grant stepped down by the same percentage. The Associations would thus cease to have been grant aided after a period of 10 years. The difficulty of attaining this aim in view was increased by the depression through which British industry was passing, and it did not succeed. Before the end of this second quinquennial period, it was evident that pursuit of this plan would result in the demise of many Associations and it was abandoned in favour of a more feasible scheme. This was known as the datum line scheme and consisted in making the following offer of grant. Up to a certain figure of industrial income decided on by the Department and placed at a fairly modest amount, no grant would be paid against it, but for all income above the datum figure, £ for £ would be given up to a sum equal to the datum figure. Thus if the maximum grant were earned, the Association would receive a grant of 10 for £1 of industrial income. This modification of the grant scheme saved the Associations, and their governing bodies were enabled by means of it not only to feel some assurance that the movement would be given a chance to prove itself, but gave them real inducement to place their organisations on a sounder and enlarged financial footing. One of the great mistakes made by the Department in the early years of the scheme was to allow the formation of a Research Association on a totally inadequate basis. Today and in the light of experience the Department considers £10,000 a year an appropriate minimum on which to build. After the datum line scheme had been operating for a number of years, the present plan of block grants and additional grants was devised to replace it: the underlying intention being similar. I will describe the current practice a little more fully later. The chief difference lies in (a) the increased stability engendered by the block grants (b) the power of the Department to vary the terms to meet different circumstances and conditions. It is more elastic than the datum line scheme but not so generous in all cases. A greater measure of industrial support is required in cases where it is reasonable to expect it.

Underlying Policy of the Scheme

3. The Research Association scheme was an experiment which had never been tried in any country in the world and was designed to meet the individualistic outlook of British manufacturers and to quell their inherent dislike and distrust of Government interference. Throughout the twenty-five years of the existence of the scheme, it has been the policy of the Department to stress the autonomy of the Associations and to administer the grants paid in such a way to convince industrialists that real liberty (though not licence) was accorded to the Associations and their governing bodies. The underlying purpose of this policy was to secure so far as possible, the utilisation of the results achieved. It was felt that if an industry were made responsible for drawing up the programme and for seeing that it was carried out, the results to which the members had been party throughout would be used and put into practice. Results achieved by a Government laboratory and possibly published thereafter would be more likely to redound to the benefit of foreign competitors than to British firms who, as a rule, study but cursorily (compared with foreign firms) the results that are achieved in various quarters.

4. There is one exception to the complete autonomy of a governing body in framing the programme of an Association. The majority of members might

wish to explore a certain field in which one member-firm had established a predominant position by patents or undisclosed processes at great cost to itself. Under the constitution that firm, however considerable its subscription to the funds of the Association, could be voted down. A firm in this position has the right to appeal to the Department against the inclusion of an investigation likely to prejudice its position. The Department on receiving such an appeal can exercise its discretion and decide whether the investigation should or should not form part of the programme. In point of fact I do not recall a case where this position has arisen but it was a possibility foreseen by the Department when the scheme was originally framed. The provision is contained in the common form Articles of Association.

5. Another underlying intention of the Department's general policy was to increase the scientific mindedness of British Industry. Certain industries were not lacking in this respect, e.g. the scientific instrument industry and the electrical industry, but others were far from being in this position. It would be invidious to quote examples. If British industries could be made to attach more importance to the application of science to their processes and materials the scheme would do a great service, apart from any outstanding results that might be achieved. It was therefore an educative scheme as well as one designed to increase the material prosperity of member-firms which cooperated in it.

6. I mention these first principles on which the relationship of Research Associations to the Department is based so that you may appreciate the why and wherefore of the more detailed arrangements I will describe in a moment. It is also important that you members of the staff of almost the youngest Research Association (though it is the most liberally financed) should realise the inheritance into which you have entered. The Association is only five or six years old and naturally you do not know the inwardness of many of the arrangements which govern the operations to which you contribute by your labours. Your Association has been spared the vicissitudes suffered by many of the earlier formed Associations, and has benefitted by the experience gained elsewhere. But the short life to date of your Association has not enabled it to acquire knowledge of the underlying principles to the same degree as Associations of greater age.

Nature of Grant Aid

7. The grants from the Department are, and always have been, essentially income raising in nature and are given to an Association in order to establish it on a reasonable financial basis and to encourage its expansion to a more satisfactory extent. The present scheme of grant aid consists in making a block grant in respect of a specified industrial income, while over and above that figure and offer is made of additional grant, on the basis of so much grant for so much income above the initial sum required to earn the block grant. An upward limit for the additional grant range is specified. Thus in the case of B.C.U.R.A. the Department has offered a block grant of £20,000 provided at least £80,000 is raised from industry, and additional grant up to another £30,000 if £70,000 is raised over and above the first £80,000. In other words, the Association has a potential income of £200,000 of which £150,000 has to be raised by industry. If more than £150,000 is raised in a year the excess would not earn grant.

The grants are in no way for services rendered to the State, except in the broadest possible concept as redounding to the national welfare. Increased prosperity of the industrial firms of the country naturally results in larger profits and therefore in larger revenue from taxation. But only to this extent does the State except to profit financially. The crucial condition of grant is that there shall be due prosecution of research for and on behalf of the industry concerned.

Payments by State for Services Rendered

8. Sometimes the State, either by way of a Fighting or a Supply Service, may say "such and such a Research Association is the best body in the country

to do this job for us." In that case the Government Department concerned will pay for the service so rendered and this applies equally to a Station of the Department itself.. The normal grants given to the organisations by D.S.I.R. do not carry with them any obligation on Research Associations to do something for nothing for the State; if a service is asked for the results belong to the Department of State which pays for the service desired. If the answer can be supplied from existing knowledge, the Association naturally gives the information gratis.

Grant Earning Income.

9. The income received from industrial sources by way of annual subscriptions and donations is taken into account by the Department in computing its grant, provided these receipts are given for the general research purposes of the Association and for carrying out the annual programme. If extra industrial subscriptions are made by firms for accelerating certain items in the general programme in which they are specially interested, these also are grant earning.

Rate Exemption.

10. A point of some financial interest is the exemption from payment of rates enjoyed by most Research Associations. Some years ago this matter was explored, since under an ancient Statute scientific societies and the like, not working for profit, can be exempted from the payment of rates. The Registrar of Friendly Societies having considered the general question is prepared to issue his certificate accepting any Research Association operating under the model Memorandum and Articles of Association as falling under the Statute. On the strength of that certificate an Association proceeds to refuse to pay rates to the Local Authority which can appeal to Quarter Sessions if it thinks fit. This was done in a notable case (the Non-Ferrous Metals Research Association) which eventually came before the Lord Chief Justice who ruled in favour of the Association. So far as I know all Research Associations which do not trade, *i.e.*, do not manufacture themselves for sale any product arising out of their researches, enjoy this exemption. The exemption applies, of course, only to the laboratories and offices of the Association and not to any property or houses on the land of the Association leased to members of the staff for their personal accommodation. One Association which, contrary to the advice of the Department, decided that it was expedient to manufacture in smallish quantities a product that it had devised and to sell it to members, lost thereby their rate payment exemption.

Control of Expenditure.

11. The income of the Association (including the grant from the Department) is spent at the sole discretion of the governing body for the furtherance of the programme. The Department has no voice in the apportionment of the income nor has any section of members. Thus a section of members cannot say "we have found £x and we insist on £x plus a grant equivalent being spent on the section of work in which we are interested." The governing body can decide to spend £x multiplied by 3 on the item or can decide to spend one-third of £x. In actual practice, of course, a governing body sees that the needs of its various sections of members are fairly met.

Ownership of Results.

12. All results arising from the general programme are the property of the Association and its members, including patents. The State claims no part in any financial advantage gained thereby.

When a result has been achieved and embodied in a report, the submission of that result must be made to the Department who will decide whether, in the national interest, the result should be withheld (a) from open publication, if that is proposed or (b) from dissemination to members generally. This power of veto during times of peace has never been exercised, though naturally under war conditions it has been. The Department also claims other rights in the dissemination of a result. It can, without question by the Association, communicate the result for the confidential information of another Home Government Department. But that other Department cannot pass the information on to any firm with whom it is in commercial relationship. The Department

also has the right to inform another Research Association of the *title* of a report which is likely to be of interest to that other Research Association. It then is a matter of negotiation between the two Associations how far, and on what terms, the contents of the report shall be made available.

If a result is to be patented, the "complete" specification must be submitted to the Department, for the filing of a "complete" may lead to publication. It is not obligatory on a Research Association to send a "provisional" specification to the Department, though it is not uncommon for a Research Association to do so. The filing of any specification in a foreign country requires the prior consent of the Department, for here again publication is involved.

In connection with the matter of publication of results generally it is important to bear in mind that the Department of Scientific and Industrial Research, as the sponsoring Department, is often called upon to defend publications by Research Associations to other Departments or to outside critics. For this reason, if any claims for anticipated results are made in such reports, they should be guarded. A fair and unbiassed claim should be attempted which should err, if at all, on the side of understatement.

Availability of Results.

13. The results arising from the general programme are available to all members and a particular result cannot be limited to a particular section. As a matter of fact some of the results may be of small interest to many members and they may not desire to have them but they have the right of access. There must be availability of results to members in respect of all work constituting the general programme.

We now come to a different category of investigation . A firm or a group of firms may wish a piece of work undertaken for and on their own behalf, and the results are to be confined to that firm or group of firms. The availability of results is to be circumscribed.

The first thing to be decided is whether the normal work of the Association will permit of the investigation being undertaken without interference with the work for the main body of members. If that proviso is satisfied a form of agreement is drawn up which requires the approval of the Department—exercised in the interests of the members as a whole, and of the country at large. The full cost of the investigation must be borne by the interested firm or firms and the contributions so made are *not* grant earning. They are paid for services rendered and not for the general research purposes of the Association.

Extra Mural Investigations.

14. It may happen that some sections of the general programme could be best dealt with *extra-murally, i.e.*, at some University where a particular professor is an acknowledged authority in the field concerned. In such cases it is highly desirable to draw up precise understandings and frame a contract for the work. Not only has the cost to be computed and agreed but the availability of the results clearly defined. The arrangement will normally be with the University Institution which, in return for £x per annum for a specified period to meet the cost of the salary of the required assistant to the professor and materials, etc., undertakes to conduct the investigation and to pass on the results to the Association. No publication of the results in a scientific journal or otherwise can be made without the prior consent of the Association—the owner of the results. A contribution to the general work of a University Chair should not be made, for that is in effect a subsidy by a State aided organisation of the general work of a University in receipt also of State aid. If the Association is only a part contributor to the cost of an extra mural investigation, it is most important that the availability of the results is clearly defined at the outset.

15. It is not uncommon for two Research Associations to agree to conduct a joint investigation of mutual benefit to both their bodies of members. Here again the availability of results needs clear definition at the outset, but normally the results are made available freely to the members of both bodies. Should

one of the Research Associations become the sponsor for the investigation and receive financial assistance for it from the other, the money so received would not be grant earning because it would be already impressed with State aid, despite the fact that the work was made part of the general research programme of the sponsoring Association.

General Co-operation with Department.

16. I have now sketched in broad outline the present relationships between the Department and autonomous Research Associations and explained the arrangements governing co-operation in several directions, but I have not dealt, except by inference, with the assistance given by the Department to a Research Association in kind. The general co-operation engendered and fostered by the Department should be realised. All the experience of the Department is available to any Research Association and after the passage of time there are few questions arising which have not previously arisen elsewhere. The main work of the Stations of the Department is also freely available to Research Associations and contacts between Associations and Stations are encouraged. In short, the work of Associations is a complement to the work of the Stations and the Associations are to be considered as an integral part of the Department's ambit of operations

17. This brings me to the differentiation between what is done at the Stations of the Department and what Research Associations should do for industrial research in the country. Broadly speaking the Stations are engaged upon research of benefit to the whole community rather than to any particular industrial section of it. All the people need shelter, food and water and so the Building Research, Food Investigation, and Water Pollution Research Boards have been established. Research into the products of forests is needed for the best use of timber and the Forest Products Research Station deals with the tree after it is felled. The National Physical Laboratory and the Geological Survey deal with somewhat wider issues, *viz.*, the maintenance of standards and the survey of the geological deposits of the country. It is true that the National Physical Laboratory deals with other things as well, *viz.*, help for the Shipbuilding Industry at the Tank. But the time is not far distant when a Shipbuilding Research Association will probably be formed and the somewhat anomalous position that exists in that field will be put on a footing comparable with that for other industries.

Co-operation with Fuel Research Station.

18. I have left the Fuel Research Station for more detailed consideration, since that is the Station of the Department with which we are most closely concerned.

The Fuel Research Station was established many years ago to investigate the nature, preparation, and utilisation of fuel of all kinds, both in the laboratory and on a large scale. Much more attention has been given to coal and its products and by-products than to other fuels, as coal is rightly considered to be one of the most important national assets.

19. There are certain general principles that should be borne in mind in considering the relationship between the Fuel Research Board and the industrial research associations including C.U.R.A., the Gas Research Board, the Electrical Research Association, the Iron and Steel research organisation, the Refractories Research Association—and, if formed, a Hard Coke Research Association. First, the Coal Survey is a national endeavour and must remain the responsibility of the State, acting through the Fuel Research Board and the Geological Survey of the Department. Second, the Fuel Research Board must remain the impartial advisers to the Government on fuel questions affecting the national welfare and be the supreme body of advice on those issues.

The aim of the Research Associations is to undertake investigations of direct concern to the industries they represent.

20. To bring about a satisfactory system of co-ordination and to avoid unnecessary duplication of effort—some degree of duplication may, and very likely will be, desirable—a Standing Conference has been set up on which all the bodies I have named will be represented. The Conference will be presided over

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by the Chairman of the Fuel Research Board, and will review the respective fields of work, not to issue orders that such and such an item must be dropped or such and such an item added, but to secure general agreements within which each body represented can, have a clear picture of their respective fields and, where overlapping is to occur, that each body may know so that touch can subsequently be kept. The Conference will not be executive in function, nor will it interfere with the autonomy of the bodies represented upon it. In the ultimate issue, of course, the Department has the last word, for under the conditions of grant it can say "there is not due prosecution of research"; and under the conditions of grant the Department is the arbiter on the interpretation of that ruling phrase. But that position will not arise, for the Department would only use its powers in this respect in the unlikely event of an Association failing to be reasonable and as a last resort.

21. I can well imagine the formation of similar Conferences, either standing or *ad hoc*, to deal with situations affecting two or more Research Associations and a Station of the Department. For example, the building industry consists of a somewhat heterogenous collection of sub-industries all of which are involved in the problems of post-war building construction. The Department might think it a good plan to bring together for corporate deliberations such bodies as its Building Research Station, C.U.R.A., the Paint Research Association, the Iron and Steel research organisation, the Non-Ferrous Metals Research Association, the Cast Iron Research Association and possibly the Refractories Research Association. All these bodies from different angles might contribute to a solution of the many interrelated problems involved and might sketch a plan of campaign in which each would play its part with full knowledge of what the other organisations were going to do. That is the kind of national co-operation which the Department is in a specially favourable position to bring about by reason of its close relationships with all concerned in industrial research.

22. I conclude by repeating that the Association, and you members of its staff, should remember that the Department is always anxious to help and is approachable in small matters as well as large ones; on research problems and on administrative matters. Do not hesitate to seek its advice and that of its officers when you are in a difficulty on which the Department may be able to help. I hasten to add that such approaches should be made through the right channels and I am not prompting junior members of the staff to address letters with bright ideas or requests for help to the Head of the Department! The Department is a large organisation and responsibilities are naturally delegated to the various officers in charge of its branches and divisions. They are the people from whom help and guidance in all but the largest issues will be forthcoming.

V.—ARE YOU RESEARCH—MINDED?

Industrial Research: what it Means to British Industry.
By Sir Harold Hartley, F. R. S.

The Need for Research in Industry.

The prosperity of Britain after the war will depend more than ever before upon the efficiency and progressiveness of our industries. The loss of our foreign investments and the possible diminution of the payments to us from abroad for services rendered will necessitate a considerable expansion in the value of our exports if we are to increase or even maintain our standard of living. Furthermore, this increase in exports will have to be brought about despite the industrialisation of other countries which before the war were mainly producers of raw materials. Success can only be won if our products are better, more attractive or cheaper than those made by our competitors or in our customers' own country.

Similarly, in the home market, our own products must hold their own, and we must make the most of the limited range of our native raw materials.

This formidable task can only be achieved by using to the full our inventiveness and technical skill both to increase the efficiency of our older industries and to develop new commodities which will hold their own in the markets of the world. In the nineteenth century our natural genius and craftsmanship gave us industrial supremacy, but we were then cultivating a virgin field and, until the close of the century, we had few competitors. Now the position is very different, not only because of the growth of industry abroad, but because the easy inventions and obvious developments have already been made. Nature now only yields her further secrets as a result of much more prolonged and careful searching. Haphazard enquiry must be replaced by organised and systematic study.

Only research can refashion existing industries effectively and create new ones. Developments sometimes occur with surprising rapidity, as was the case with radio and rayon, and everyone knows the remarkable scientific developments like radiolocation which have occurred under the stress of war. There is no reason why the post-war problems of industry should not equally be solved by scientific research, provided it is adequately supported.

In the future the advantages Britain possesses in the skill and traditions of her craftsmen will depend more and more on the science that directs their efforts. Labour and research must work hand in hand.

Great Britain and Her Competitors.

Germany and the United States are usually quoted as outstanding examples of countries which have utilised the services of science in the development of industry to a far greater extent than we have in Great Britain. Direct comparisons are difficult and misleading in that much valuable work has been done in the industries of this country without it being specifically termed industrial research, whereas Germany, and particularly the U.S.A., have given greater prominence and publicity to their industrial research activities which they have recognised as possessing a definite sales appeal. Nevertheless, despite some outstanding exceptions, in this country there has not been a general appreciation of the value of science in industry, and the amounts spent on research have been correspondingly less.

The published figures of expenditure upon research in America show that the amount spent by that country in 1940 ran into hundreds of millions of dollars.

Figures for war-time expenditure on research in this country are not available, but a study of pre-war expenditure by both countries shows without question that this country spent nothing like enough in comparison with the United States.

The greater use which the United States makes of scientific knowledge is strikingly reflected in the character of their exports which, to a far greater extent than the exports of this country, are the result of modern invention and design.

It is important to emphasise that these contrasts are in no way due to any lower standing of British science. In both the world wars British scientists have proved that they can more than hold their own if they are given equal facilities and support. All they need is the same opportunity in peace as in war.

It is impossible to avoid the conclusion that if this country is to maintain its position in the world markets, our industries must greatly increase their attention to research as soon as the progress of the war makes it possible. There is danger in delay: markets once lost are not easily regained; and industrialists must be taking active steps now to organise this aspect of their post-war activities.

The organisation of Research in Great Britain.

At the present time research in Great Britain is carried on in five main groups of establishments:—

Laboratories of the Universities and Technical Colleges.

Research Stations of the Department of Scientific and Industrial Research, and of the Agricultural and Medical Research Councils.

Research Associations supported partly by industry but aided by grants from the D.S.I.R.

Research Laboratories maintained by private firms.

Research Establishments of the Fighting Services.

The Laboratories of Universities and Technical Colleges.

Great industrial developments usually depend on fundamental discoveries; thus the electrical industry grew from Faraday's researches on electro-magnetic induction, and the radio industry sprang from the work of Hertz on electro-magnetic waves carried out in a university. In more recent times the technique of radiolocation was first devised and used for a purely scientific purpose without any thought of its practical application. These examples illustrate in a striking way the unexpected practical significance of the by-products of pure scientific research.

It is in the University laboratories, the outposts on the frontiers of knowledge, that fundamental research is mainly done. At any time a new industry may be born there which will meet some new human need. It is in the atmosphere of the University laboratory, too, that the men on whom we shall have to rely as leaders of industrial research are bred and trained.

Business therefore has a direct interest in seeing that research at Universities and in Technical Colleges is adequately endowed.

Research Stations of the Department of Scientific and Industrial Research.

These now consist of the National Physical Laboratory, the Fuel Research Station, the Building Research Station, the Forest Products Research Laboratory, the Road Research Station, a group of stations under the Food Investigation Board, the Water Pollution Research Laboratory, etc. The programme of each station is drawn up on the advice of a Research Board consisting of outside scientific men and industrialists, with representatives of interested Government Departments. There are a few additional Research Boards which do not maintain laboratories but place their work extra-murally at Universities and elsewhere.

The National Physical Laboratory was originally established for the maintenance of national standards, but it is now organised into a group of departments, *e.g.*, aerodynamics, metallurgy, engineering, which carry out research, mainly of a fundamental nature, directed to industrial needs. A certain amount of research is also done for Research Associations and for individual industrial firms.

The other large stations deal with the nation's general needs in regard to food, housing, fuel, roads, etc. They, too, undertake work for Government Departments and for industry and are always ready to act in an advisory capacity.

The results of individual work for private firms are, of course, communicated in the form of a confidential report, and the full cost is paid by the firm. The results of the general programme of work are made available in annual or special reports sold through H.M. Stationery Office. Firms, therefore can benefit from all this work, as well as having access to the advisory and information services of the stations, usually without any payment.

Research Associations.

These were started at the end of the last war with the help of a million pound fund voted by the Government to the Department of Scientific and Industrial Research. There are now twenty-four of them,* and they are self-governing bodies, supported voluntarily by firms engaged in the industries for which they cater, or in a few cases by a levy on the raw materials of the industry in question. The Department of Scientific and Industrial Research supports the associations financially by means of annual grants to an amount depending on the subscriptions from industry. This year the total incomes of the associations

* See Appendix for list of Research Associations.

will be over £800,000, of which £275,000 will be Government grant. The subscriptions vary with the size of the member firm, being in some cases as low as £10 annually for the smallest unit. Most of the associations possess their own laboratories, but some of their work is done in Government or University laboratories or in the laboratories of member firms. The control of the associations is in the hands of councils elected by the members; the results of the work are confidential to members in the first instance, but, in fact, much of it is subsequently published and added to the general fund of knowledge.

Although most, of the associations have steadily expanded in size and usefulness, they are not yet on a scale commensurate with the industries they serve. One of them is now planning to spend £200,000 per annum, but only four of them have an expenditure exceeding £50,000 per annum, which represents 0·06 per cent. of the turnover of the industries concerned.

It is not only the more modern types of industry that have co-operated in founding research associations. Out of more than twenty such bodies only three or four can be described as serving industries which have developed from recent inventions and research. The great majority relate to industries that have been established for a century or more, showing that traditional methods are equally responsive to scientific analysis and the developments that spring from it.

Private Industrial Research Laboratories.

These were first set up in the electrical, chemical, and metallurgical industries, but other industries have since followed suit. Naturally, the larger industrial units have found it easier to bear the cost of setting up research facilities of their own, and even in the smaller firms, routine laboratory testing has become a necessity, and this not infrequently leads ultimately to the conduct of actual research.

Although some of the work carried out is of a fundamental character, a proportion of it is necessarily of a more immediate and practical character concerned with a firm's day-to-day problems.

Hardly any of the firms who possess research laboratories confine their expenditure on research to their own establishments. They are, as a rule, the strongest supporters of the Research Associations and make the most use of the results obtained in the D.S.I.R. stations and at University laboratories.

The place of Research in Industrial Firms.

For large firms there should be little difficulty in establishing a research department of their own and in building and equipping the necessary laboratories. The first step is to decide on the problems which invite attack, the next to decide on the scale of the attack, to find suitable staff, and gradually to make research a recognised part of the organisation. This will take time, as a research staff have to learn their problems. Confidence will be established between them and their colleagues as they show their ability to help in the day-to-day difficulties, "trouble shooting" as the Americans call it. The long-range problems need patience and only a part of this work can be expected to bear fruit, but it is surprising how quickly research begins to give results, sometimes in quite unexpected directions. In time the whole concern will become research-minded, and in America it is not unusual to find the head of a research department with a seat on the board.

For smaller firms the starting of research is not so easy, and there are so many of them. In our five largest industries, for example, there are nearly 5,000 separate undertakings, of which only 126 employ more than 1,000 people each. It was for smaller firms that the Research Association movement was largely conceived, since by co-operative research an annual subscription of, say £100, may ensure participation in the results of a research expenditure of £20,000 per annum or more.

However, the payment of such a subscription is only the beginning. It is essential, even in the smallest unit, that there should be at least one member of the staff with sufficient scientific training to follow the work carried out in

the Research Association and interpret it to his firm. Such a man, too, can be of the greatest value in appraising the results and implications of other published research bearing on his firm's interests, and in general acting as a scientific adviser and consultant. Such men should be a more common feature of our industries, and they should be accorded a status which will ensure their voices being heard. No firm should be deterred from taking up research merely because it cannot afford in the first instance an expensive laboratory and equipment. It is the quality of the man that counts.

The Relation between Research and Development.

Industrial researches are undertaken either to increase the efficiency of existing practice and lower costs or to discover new products or new processes.

Development is the stage at which promising research results are tried out on a pilot plant in order to adapt them ultimately to large scale production. Not infrequently the same research staff, and to some extent the same experimental technique, will be employed in the development stage. For this reason the term Research and Development Department is not uncommon, and many of the Research Associations possess Development Sections, or at least, Development Officers.

The stage between the perfection of a new process and its industrial application may be prolonged and difficult. It is here that the heaviest expenditure is likely to be needed.

Research Men and where to Find Them.

Success in industrial research depends on several qualities— imagination, resourcefulness and initiative, coupled of course with scientific instinct and a scientific training. Some men are best fitted for long range fundamental work, others for applying its results and solving immediate difficulties. They should all be good mixers, for team work is essential.

Research is apt in many minds to conjure up a limited picture of a chemist in a laboratory, and whilst it is true that the chemist often forms the starting point around which a research team grows, industry now employs physicists, metallurgists, mathematicians, research engineers, biologists and geologists, as well as specialists in more restricted fields such as radiology, corrosion, statistics, etc. Information officers, with a knowledge of foreign languages, are also found in the largest research establishments, since it is so essential to keep abreast of published scientific work at home and abroad.

A team of research workers usually consists of a number of University graduates with assistants, some of whom may ultimately qualify by taking external degrees or by passing the examinations held by the great professional institutions.

The graduates are recruited from the Universities mainly as young men in their early twenties, and they are sometimes given some experience in the works before going into the Research Laboratory. It is usual to pay such men a starting salary of £250 and upwards. The usual method of finding them is by advertisement in the technical and scientific Press, or by direct application to the various University Appointment Boards.

Non-graduate assistants are usually recruited from the secondary schools and technical colleges at an earlier age and lower salary than the University graduates.

The success of a research laboratory depends on the men with ideas. Only experience can show who they are. They may come in as University graduates, as assistants or as laboratory boys. Encouragement and a watchful eye are needed to find them.

The Cost of Research.

It is difficult to lay down any general standard of research expenditure. It has been stated that whereas the total U.S.S.R. budget for science is 1 per cent. of the national income, ours is but one-tenth of one per cent., and that of the U.S.A. three-tenths. Taking expenditure by individual American

trades we find the ratio of the research budget to gross sales is for radio apparatus 1·6 per cent., for electrical communication 1·4 per cent., and for chemical industry and rubber products 1 per cent., but in the older industries the ratio is much less.

Whatever the scale on which research is begun, it is a general experience that its budget increases as it is found to be more and more indispensable.

The initial step of subscribing to a Research Association is not costly. In many cases a small firm would be assessed for subscription at ten to twenty guineas, and not many of the larger units subscribe more than £1,000 per annum. In two typical Research Associations at the present time the average subscription of members is only about fifty pounds. For this outlay, the subscribing member participates in research costing 500 times this figure. However, subscriptions to Research Associations must in future be larger in order to give them more adequate resources.

The cost of a research department obviously depends on its size. The small firm may employ only one scientist, costing, say, £500 a year and laboratory expenses. In the larger research units the annual cost may be taken as roughly equivalent to the capital cost of the laboratory and equipment. Thus, a laboratory costing £10,000, in which a considerable volume of research work could be done, would require a similar annual expenditure in salaries and running costs, representing 1 per cent. of a turnover of £1,000,000.

It is important to remember that the running costs of research are allowed by the Inland Revenue as a deduction for income-tax purposes. This applies equally to annual subscriptions to Research Associations, except in respect of any entrance fee and specific donations for capital purposes.

How Research Pays a Dividend.

That research not only pays but is of vital importance to our national existence is clear in war-time. Think what we owe to the supremacy of our aircraft, thanks to research in aerodynamics, light alloys, and the internal combustion engine; to the rapid solution of the problem created by the magnetic mine; to the development of radiolocation. Less spectacular, but of almost equal importance, are the results of scientific research into the use of alternative materials which we have had to employ either to save shipping space or because we have been cut off from our accustomed sources of supply.

What research has meant in peace-time can be seen from the savings that have come from a few inventions. It is estimated that the gas-filled lamp developed by Langmuir represents an annual saving in the cost of domestic lighting in this country alone of £50,000,000. The improvement in the efficiency of the petrol engine due to lead ethyl saves over 2,000,000,000 gallons of petrol a year. The use of accelerators for vulcanising rubber has saved capital outlay on moulds estimated at £16,000,000. Research on motor tyres has increased their average life from 3,000 miles to over 20,000 miles.

Naturally, these vast savings have been reflected in the profits and prosperity of the industries and firms responsible for these great technical advances.

The first question any firm will ask is, what return can we expect from expenditure on research? The answer is partly given above, for there will always be brilliant prizes to be won. But the short answer is that no firm can afford to neglect research, as it is the only safeguard of the future. The time may come when the public will look at the research expenditure as an index of a firm's prospects; if those figures were all available to-day they might reveal the secret of many failures and successes.

It would be easy to multiply examples like those given above, but the best proof is that firms who have once begun to do research have never dropped it. On the contrary, they spend more and more. Even during the great slump in the United States it was remarkable how few firms cut their research staff, and some were actually increased in size.

When we are ill we send for a doctor. He can delay, but he cannot prevent old age. Research is the elixir of life of industry, ever renewing its youth and vigour.

Therefore—

Make Your Industrial Friends Research-Minded.

so that when the war ends they may make the utmost use of scientific discovery and experience in attacking their peace-time problems.

Tell them—

1. To have at least one member of their staff with a scientific training.
2. If there is a Research Association for their trade, to join it now.
3. If there is no Research Association, to urge their Trade Association to approach the Department of Scientific and Industrial Research* in order that a Research Association may be formed and at the same time advise the Federation of British Industries.†
4. If their trade has no Trade Association and no Research Association and they do not themselves employ research staff, to apply to the Federation of British Industries for advice.
5. If they have no research staff and do not know how to proceed, to apply to their Research Association, if one exists, or to the Federation of British Industries.
6. If they are in a large way of business, to consider the establishment of a research laboratory alone, or with associated or kindred firms in addition to joining the appropriate Trade Research Association, if there be one.

APPENDIX.

List of existing Research Associations, 1943.

British Association of Research for Cocoa, Chocolate, Sugar Confectionery and Jam Trades.
British Boot, Shoe and Allied Trades' Research Association.
British Cast Iron Research Association.
British Coal Utilisation Research Association.
British Colliery Owners' Research Association.
British Cotton Industry Research Association, including Rayon and Real Silk Departments.
British Electrical and Allied Industries Research Association.
British Food Manufacturers' Research Association.
British Iron and Steel Federation (Iron and Steel Industrial Research Council).
British Launderers' Research Association.
British Leather Manufacturers' Research Association.
British Non-Ferrous Metals Research Association.
British Pottery Research Association.
British Refractories Research Association.
British Scientific Instrument Research Association.
Gas Research Board.
Institution of Automobile Engineers (Automobile Research Association Committee).
Internal Combustion Engine Research Association.
Linen Industry Research Association.
Printing and Allied Trades Research Association.
Research Association of British Flour Millers.
Research Association of British Paint, Colour and Varnish Manufacturers.
Research Association of British Rubber Manufacturers.
Wool Industries Research Association.

VI—INDUSTRY AND RESEARCH.

Report of the F.B.I. Industrial Research Committee.

October 1943.

The following Report, which has been adopted by the Grand Council of the Federation of British Industries, was prepared by a special Committee,

* Park House, 24, Rutland Gate, S. W. 7 † 21, Tothil Street, S. W. 1.

appointed by resolution of the Executive Committee in November, 1942. A Summary of the Report begins on page 21. The Committee consisted of the following:—

Sir William Larke, K.B.E. (Chairman).

Dr. S. B. Bagley.	Dr. W. T. Griffiths, F. I. C., F.Inst.P.	Dr. C. C. Paterson, O.B.E., F.R.S.
Mr. W. Bond, F.I.R.I.	Dr. W. H. Hatfield, F.R.S.	Sir Felix J. C. Pole.
Dr. W. T. K. Braunholtz, M. A., F.I.C.	Mr. A. L. Hetherington, C.B.E.	Mr. R. K. Sanders, M.A.
Dr. P. Dunseth, O.B.E., M.A.	Rt. Hon. Lord Melchett.	Dr. R. E. Slade, M. C.
Mr. T. A. Fairclough.	Mr. R. O 'F. Oakley, O.B.E.	Mr. S. K. Thornley.
Dr. W. H. Glover, F. I. C.		Mr. H. Withinshaw, M.C.

Introduction.

1. We were appointed as a Committee "to consider the question of Scientific Research in relation to Industry." Although in fulfilling our task we have concentrated more especially on considering, in terms of the present, the extent to which Industry itself carries on research and development, and the facilities available for so doing, we do not in any way overlook this country's heritage from the past. British discovery and invention have played a predominant part in laying the foundation of the material civilisation of the modern world.

2. While appreciating that the benefits of science are made available to humanity largely by practical application through industry, we recognise that without fundamental discoveries, and the formulation of scientific knowledge there could be no such outcome. Research and technical development by Industry for its own needs are a natural growth from past and present activity and enthusiasm on the part of individuals.

3. Large industrial organisations have long set up important research and development departments of their own staffed by a scientific personnel. The present position of British industry owes much to the existence of organisations of this type. The scientific and professional Institutions have also done much to stimulate and organise research. With the advent, in 1917, of the collective research association movement, sponsored by the Government through the Department of Scientific and Industrial Research, and supported by the larger firms in the industries concerned, it became possible for smaller industries and firms to take advantage of research facilities which individually they were unable to provide for themselves.

4. We are once more passing through an unusually critical period in our national economic development and international relations. The position and possible influence of scientific research in connection with our industries on these relations and on the standard of living require the most urgent, careful and detailed consideration. Various aspects of this problem are reviewed below, and certain recommendations are submitted with a view to fostering the growth of industrial research and development in this country.

5. In fulfilment of our terms of reference we have considered the problem under four main headings, namely:

(a) the importance and achievements of industrial research and development;

(b) a description of the present position and organisation of industrial research;

(c) an assessment of the present position and organisation, and directions in which it might develop;

(d) the desirability, or otherwise, of new machinery for the prosecution of industrial research and development.

The Importance and Achievements of Industrial Research.

6. The importance of industrial research and development in the national economy now receives almost universal assent. British industrial research and development has a most imposing record of achievement to its credit, most of the industries on which our modern civilisation is based having originated in the United Kingdom. Many of our industries, for example the electrical and chemical industries, are wholly based upon continuous research, and could

not have been brought into existence or maintained without it. To cite a different type of instance, Britain's outstanding achievements in the war in the air have been in large measure due to the superiority of British aircraft which is the outcome of research and development carried on in engineering and aerodynamics and on materials over many years, even during periods of severe depression, and to original and phenomenal developments in the sphere of radio location. The British contribution to technical progress has been very great in the past and there is at present no sign of diminishing enterprise or originality.

7. For the future, research and development will have an even greater part to play. It is generally conceded that the two major tasks with which industry will be faced after the war are the provision of the fullest measure of employment for the people of this country, and the achievement of the highest possible flow of exports, on which capacity to import depends. For upwards of a century Great Britain was the leading exporting nation, due to its early industrial development. This position can only be recaptured by establishing a high degree of superiority and originality in industrial products. British industry will require not only to maintain the highest measure of productive efficiency, but to introduce new materials, to develop new products and, through collaboration between the scientific, technical and productive personnel of industry generally, to mobilise the whole of our industrial resources in the interests of national prosperity. Thus the commercial potentialities of British industry must exercise a profound influence on the nature of and the priority accorded to the solution of research problems.

8. The case for research on national grounds is self evident. It must also make its appeal to the individual producer in such a manner that those responsible are convinced that it is in their interests not only to devote resources to the initiation or furthering of research and development within their own organisations, and to give to their own research staff an appropriate position in the hierarchy of the organisation, but also to support the collective research organisation of their industry. There are very many prosperous companies which maintain their own research laboratories, expending large sums of money upon them and which also find it advantageous to give strong support to their industrial research associations.

9. The application of research is a certain means of increasing employment by the improvement of existing and the creation of new industries: conversely, the lack of it spells stagnation and ultimate bankruptcy.

10. Lip service to research is often paid by firms or industries which believe that they have no problems requiring scientific investigation. This attitude is not necessarily one of apathy but rather of lack of experience in the application of science to their productive processes which have been developed empirically. It is not suggested that all industries and every firm provide equal opportunities for the application of research, since the nature of the product and the prevailing size of the producing unit are factors having an important bearing. It is nevertheless our considered view that no industry can maintain progress without research, and that a wide field exists in which research is not being undertaken at all or is being undertaken on an inadequate scale, to the detriment of the competitive power of the industry or firm concerned and thus to the detriment of the national standard of life.

11. It is our hope that this Report will help to focus attention on what is perhaps the most vital industrial question of the day, and, by so doing, assist in stimulating a proper consideration of the matter.

The Present Position and Organisation of Industrial Research.

12. At the present time scientific research is carried on by Industry along two main lines. In the first place there are the all-important research activities of individual firms, conducted in their own research departments or on their

behalf and at their expense in universities, at Government Research establishments, through research consultants and the like. Certain individual firms, which may or may not be financially connected, also have arrangements whereby they jointly maintain a research laboratory, either concurrently with, or in substitution for the maintenance of a laboratory within their own organisation. Secondly, there are the various forms of collective research activity, of which the predominant is the industrial research association.

Research by Individual Firms.

13. It was clearly envisaged at the outset of our deliberations that if any conclusions which might be reached were to be soundly based, an effort must be made to assess the extent to which research under these two broad headings is being undertaken at present and the extent of its recent progress. As regards the activities of individual firms, a difficult question was to decide on an appropriate yardstick for the measuring of achievement. It had to be borne in mind that enquiries would need to be addressed to a very large number of individual companies, whose replies would require to be collated, and also that, in the circumstances which exist at the present stage of the war, it would be unreasonable to expect the provision of detailed information. These considerations dictated the choice of (a) money spent, and (b) numbers of scientific graduates or other technically qualified persons employed, as our criteria. We are only too conscious that neither money spent nor numbers employed on research are necessarily a sufficient indication of the vitality of research at any given time or of its value in the national interest. Many results of the utmost importance have been in the past and are to-day being achieved by small groups of men with the scantiest resources at their command, but who have been and are imbued with energy, enthusiasm and a high order of scientific imagination. Money cannot create a Faraday, though it may provide facilities for his development. At the same time, expenditure and numbers employed afford some indication of the interest shown, when covering a sufficiently wide area, and we have therefore confined our enquiries to these two factors.*

14. A study of the individual returns received from firms, where these were comparable over a period, shows evidence of strong trend towards a greater awareness of the importance of research, in so far as this can be exemplified by increasing expenditure and growing qualified staffs. The global results of the enquiry show that, in 1930, 422 firms were spending £1,736,000 on research and development; in 1935; 484 firms were spending £2,696,000, while, in 1938, 566 firms were spending £5,442,000. Scientific graduates and other technically qualified personnel employed wholly or mainly on research and development in 1930 by 384 firms numbered 1381; similar personnel employed in 1935 by 432 firms numbered 2566, while in 1938 the research personnel of 520 firms numbered 4382. These results do not by any means cover all firms engaged in research and development, nor has every firm making a return been able to show the full extent of its research and development expenditure. Thus the figures considerably understate the true position. However, they are drawn from firms in a wide variety of industries and can serve as some measure of the order of the research activity of individual firms nationally considered. Owing to the incomplete nature of many of the returns, no attempt should be made closely to compare one year with another.

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* A comment is required as to the significance of the term "research" as used in connection with the enquiries addressed to individual companies. The term is often loosely used, being frequently stretched to include investigation of defective products or mere routine testing. On the other hand, to adopt a definition as narrow as "the investigation of the unknown" would be unduly restrictive. In many instances the drawing of a line between pure research on the one hand, and development on the other, is impossible, and consequently our enquiries related to both research and initial development.

Collective Research.

15. The second main line along which research is conducted is the co-operative method. By co-operative research is meant research undertaken on behalf of an industry as a whole, or at least a substantial part of it. The necessary laboratories and scientific staff are financed by the interested firms jointly. The responsibility for the programme of work is with a Council representing the subscribers, and in general the results achieved are made available to all subscribing members. Sometimes the work is done by a department of a University or by a Government Department or Government research station acting in close co-operation with, and generally at the cost of, the industry concerned. The most typical form taken by co-operative research is, however, the research association, which in addition to the subscriptions it draws from individual members, is also the recipient of annual grants (which in amount bear some definite relation to the subscription income) from the Department of Scientific and Industrial Research. The Department is responsible for ensuring that there is "due prosecution of research" on the part of the associations receiving grants from public funds. Such associations have in most cases established their own laboratories.

16. It has been possible to obtain more accurate and detailed information from the research associations than was the case with individual firms and other types of industrial research organisation. There are at the present time the following twenty-four research associations in receipt of grant:

Automobile Research Committee (Institution of Automobile Engineers).

British Association of Research for Cocoa, Chocolate, Sugar Confectionery and Jam Trades.

British Boot, Shoe and Allied Trades Research Association.
British Cast Iron Research Association.
British Coal Utilisation Research Association.
British Cotton Industry Research Association.
British Electrical and Allied Industries Research Association.
British Food Manufacturers' Research Association.
British Iron and Steel Industrial Research Council.
British Launderers' Research Association.
British Leather Manufacturers' Research Association.
British Non-Ferrous Metals Research Association.
British Pottery Research Association.
British Refractories Research Association.
British Scientific Instrument Research Association.
Gas Research Board.
Internal Combustion Engine Research Association.
Linen Industry Research Association.
Printing and Allied Trades Research Association.
Research Association of British Flour Millers.
Research Association of British Paint, Colour and Varnish Manufacturers.
Research Association of British Rubber Manufacturers.
Welding Research Council.
Wool Industries Research Association.

17. The 16 grant-aided research associations in existence in 1927 received a subscription income in that year amounting to £117,000. In 1930, there were 18 grant-aided associations, which received £162,000; in 1935, 20 grant-aided associations received £235,000; in 1938, 22 grant-aided associations received £326,000, while in 1941 the subscription income received by 22 grant-aided associations amounted to £368,000. In addition grants from the Department of Scientific and Industrial Research amounted to £58,000 in 1927, £93,000 in 1930, £113,000 in 1935, £177,000 in 1938 and to £192,000 in 1941. These figures do not necessarily represent the total income of the associations since

the receipts of some of them are swollen by donations, special contributions and grants from official organisations other than D.S.I.R., while they take no account of the considerable volume of work carried out on behalf of research associations by individual subscribers, free of charge in their own works and laboratories. On the whole, the increase in income has been steady and has persisted in spite of trade depressions.

18. The total number of subscribers to grant-aided research associations was, in 1941, over 7,100. The figures had been slightly increasing over the past few years. Some of these subscribers were corporate groups such as trade associations, so that the total number of firms covered is many times the number of subscribers. The proportion of firms in an industry which are members of a research association differs considerably from one case to another, but generally speaking subscribing firms represent the major proportion of output and capital employed in the industry concerned.

19. The expenditure of twenty-one of the grant-aided associations on research was just short of £450,000 in 1938 and in 1941 was £477,000. The total provision for 1943 is estimated at £850,000.

Comments on the Present Position and Suggestions for Improvement.

Need for Intensified Research by Individual Firms.

20. The question naturally presents itself whether research and development activity is being carried on at the present time on a scale sufficient to enable British Industry to take its proper place in the post-war world. The amounts spent on research by individual firms and by research associations, though in some instances very substantial, in total certainly represent an insignificant percentage of the value of industrial production. We are of the opinion that if one per cent. of the total value of our industrial production were expended on research and development, involving the provision of personnel and facilities, the resulting increased productive efficiency and employment capacity would yield an annual return of many times such expenditure. While it is true that the raw materials, processes and products of one industry are more susceptible to improvement by research and development than are those of another, there will broadly speaking always be the urgent need for research activity until what may be comprehensively described as efficiency of performance can be pushed no further, but this limit can hardly be said to be reached until human requirements in all their variety have been both qualitatively and quantitatively met; in effect, research and development must be a perpetually continuing activity of productive industry as providing the only basis of material progress.

21. In our view, the ideal state of affairs as regards the individual company would be that in which every industrial unit maintained its own research department on a scale commensurate with its operations, with the appropriate complement of technically qualified staff, for carrying out investigations into those problems which arise out of its productive and commercial activities. There is no doubt that in general the most profitable research is that which is carried out by the individual firm in its own laboratories in the closest possible contact with the production and commercial sides of the business. The maintenance of research and production by the staff of a single industrial unit permits of collaboration between scientist and producer and an understanding of their respective difficulties and requirements, to a degree which no alternative arrangement can achieve. It is important to bear in mind that most of the fundamental discoveries and inventions, as might be expected, have been the work of the individual industrial research laboratories, throughout the world, or of those associated more or less directly with them—such as (taking a few examples at random) television; radio valves; electric lamps; electric cables; stainless steel, and a wide range of alloys both ferrous and non-ferrous, the properties of which have made possible many modern engineering developments; steam turbines; the continuous plate glass process; a vast range of synthetic materials such as rayon, nylon, synthetic rubber, perspex and plastics in

general; the great strides that have been made in the more efficient use of coal by all the coal consuming industries; the extraction of petrol from coal and many others far too numerous to mention—all of which have resulted in either new or a substantial expansion of existing industries. In the present stage of development of industrial organisation which involves in many cases the existence of very large numbers of small producing units, it is, however, hardly to be expected that every individual firm could maintain substantial research facilities. At the same time, there exists a number of other means, whether in the shape of consultants, technical schools and colleges in suitable cases, universities, Government research stations or research associations, whereby research can be undertaken on behalf of an individual firm, and it is our FIRST RECOMMENDATION that:

(a) every manufacturing firm should take stock of its position to ensure that it is devoting to research and development the maximum effort and funds, commensurate with the nature of its problems;

(b) wherever possible it should maintain its own research department; where, however, this is not feasible, it should, at least, entrust one or more suitably qualified individuals with the responsibility for keeping constantly under review the application of research to its activities, and for initiating such investigations as may from time to time prove desirable, and create and maintain a special fund for such research and development of a magnitude compatible with its resources.

The Role of the Research Association.

22. What has been said above regarding the overriding importance of the individual firm undertaking its own research should not be taken to be little the importance we attach to collective research, even supposing that every firm was active on its own behalf. There are certain types of problem of general interest to the industry which can best be dealt with through some form of co-operative machinery. Although duplication of research endeavour is not necessarily a bad thing, it may lead to a waste of effort and resources for such problems to be dealt with individually by every firm concerned with their solution. Where practicable such problems should be made the subject of thorough investigation by trained staff having proper facilities, at a cost shared throughout the industry. This method of dealing with common problems leaves such scientific resources as the firm has available to be concentrated on problems with which it is particularly concerned.

23. The industrial research associations represent a well-tried means by which collective research over a wide field is carried on in this country to-day. We are convinced that the associations are playing a valuable part, their work being of direct benefit to the industries which maintain them not only through the results they directly achieve, but also through the stimulus which they give to the individual firms in the industries concerned to undertake their own research and scientific service, particularly from the point of view of applying to their own special circumstances the broad results obtained by the associations. Since the establishment of the research associations there has been a considerable increase in the number of firms maintaining research departments.

24. In assessing their value, it must also be remembered that the interdependence of industries is such that many individual industries and their research associations are also members of research associations representing other industries with which they have relations either as purchasers or suppliers. Thus a substantial degree of collaboration between interdependent industries in the research field has already been established to the extent that individual research associations are sometimes collaborating in work with many other associations or industries with which they have some relations in common. This is a most valuable feature of the research association movement and one which should be extended. The association which is brought about between research worker and the production management in industry encourages a more ready application of research results in productive processes.

25. With all these considerations in mind we feel the research association movement should be fostered and developed in every possible way.

26. We would, however, point out that co-operative research cannot be an alternative to or a substitute for individual research. It cannot, obviously, come into operation in any industry until that industry has developed a sense of the need for research. Neither can it expend resources contributed by a large number of members in a long-term research directed to the solution of a single problem which may be of first importance to only a limited number or even a single member. Such problems are frequently the source of great discoveries and inventions, resulting in new industries, and are obviously the field in which individual industrial laboratories have every incentive and are, indeed, best fitted to work: hence their vital importance to industrial progress.

27. On the other hand, the degree to which an association can in practice supplement the activities of individual firms and concentrate on problems of common interest as opposed to the type of problem which can best be handled by the individual firm is considerably affected by the status and composition of the industry concerned. While an association serving an industry largely composed of big companies, most of which have their own research departments, will be able to undertake fundamental investigations, an association serving an industry composed of a large number of small units, only a small minority of firms having their own facilities, is likely to concern itself with immediately practical problems including those relating to development and everyday troubles. Every association naturally tends to devote itself to such tasks as are most calculated to secure the continuing interest, and thus retain the support of its members. The ideal to be aimed at is, nevertheless, that the association should mainly concern itself with questions the solution of which is of interest to the industry as a whole, rather than with problems which should fall within the ambit of the firm's scientific facilities, and which, in our view, tend to deflect an association from its more important task.

Need for Developing Research Association Movement

28. Consideration of the figures given above with regard to the subscription income of the research associations shows that industry does not in many cases fully appreciate the benefits which can be derived from participation in collective research. Taking into account the importance of the majority of the industries maintaining research associations, it is notable that only one was spending in 1941 more than £100,000, five were spending between £30,000 and £60,000, and all but these six were spending less than £20,000. This is disappointing evidence of the extent to which industry has felt that it is worth while to co-operate financially in collective research. The expenditure by individual units in some industries is far in excess of that spent by the research association of the industry concerned.

29. The above figures relate to 1941, and the position at the present time is improving and is likely in the near future to improve still further, as the potential aggregate income of the industrial research associations working under the ægis of D.S.I.R. can now be said to be approaching £1,000,000 a year. Even this figure seems still far from adequate, and, with the qualification that subscriptions to research associations should not be made at the expense of the funds necessary for a proper prosecution of a firm's own research activity, we make our SECOND RECOMMENDATION as follows:

That the firms comprising the industries which have their own collective research associations should give the most careful consideration now to the question whether they are making to their research association a contribution, either in money or in other ways, commensurate with the work which, if adequately supported, it could perform in furthering the interests of the industry as a whole.

30. From a reference to the list of existing industrial research associations given above, it is apparent that British Industry as a whole is not completely covered by this type of arrangement for collective research. On the other hand, it would be wrong to assume that, because the name of an industry does not

appear in the list, that industry is not undertaking collective research. Various industries which have separate organisations for commercial purposes will have common research problems and consequently may support a single research association. Furthermore, additional associations are in process of being organised and the formation of still further associations is anticipated in the near future, while, as explained above, some branches of industry meet their research requirements in other ways. Yet another factor to be borne in mind is that there are some industries which, owing to their small size and limited resources, could not reasonably be expected to maintain an independent research association.

31. Notwithstanding these considerations, however, we have come to the conclusion that over industry as a whole there is room for the creation of further co-operative research machinery, and persuaded as we are of the importance of collective research in our national economy, our THIRD RECOMMENDATION is: That every industry which has not created a collective research association should set up a co-operative research committee and take steps to create and maintain a research fund which would equitably distribute the burden over the constituent concerns in proportion to their interest in the industry. The research committee would determine whether the scale and nature of the research needs were such as to require the establishment of a research association, whether a link could satisfactorily be formed with existing research associations, or whether research problems could be dealt with extramurally through university laboratories and other research establishments.

The Department of Scientific and Industrial Research

32. In considering the desirability of strengthening the research association movement regard must be had to the relations which exist between the associations and the Department of Scientific and Industrial Research. As has been mentioned above, the associations are in receipt of annual grants from the Department, the size of the grants bearing some fairly definite relation to the amounts subscribed from industrial sources. Grants from D.S.I.R. have tended primarily to be available to a somewhat standardised form of collective research activity, namely the research association, though there are exceptions. This policy is somewhat restrictive, and there are industries which, for various reasons, have organised their collective research activities otherwise than through an association, and consequently receive no financial assistance.

33. Our FOURTH RECOMMENDATION is therefore that:

(a) The Department of Scientific and Industrial Research should make the maximum use of the wide powers it possesses both as regards the amount of grant which can be made available in each case in relation to the countervailing contributions from the industrial subscribers to associations, and as regards the eligibility for grant of types of organisation for collective research which, though not research associations in name, are in fact fulfilling similar purposes.

(b) Financial provision should be made from public funds to enable the Department to increase and continue indefinitely financial support to research associations and similar organisations as a permanent feature of the national economy.

34. At the same time, it would usually be undesirable for the Department to exercise any greater degree of control of the activities of the organisations which it supports by grant than is its present practice, since it is essential that the main responsibility regarding policy and programmes should continue to rest with the respective industries.

35. While commending the general administration of the Department and paying tribute to the industrial experience associated with it for advice and suggestions as to the lines on which science can best assist industry for stimulating the industrial and commercial applications of scientific work, we suggest that it could exercise an enhanced influence on research in industry and the country generally if it were in a financial position to make grants on the advice of its Advisory Council for any research or development of national importance. Such

grants should be extended to cover capital expenditure, and individual companies should be eligible for contributions where the research is of such a character as to have no commercial value to the firm concerned and would not therefore be prosecuted at its own charges. In such cases, the dissemination of any resulting information would be at the sole discretion of D.S.I.R. The Department would also assist in developing research-mindedness in all quarters if it engaged in a greater degree of publicity with regard to its research and scientific services to industry, through articles in the press, lectures and addresses in appropriate centres in the country. These two objectives, together with the increased and continuous support for research associations suggested above, could only be achieved if the Department had control of considerably greater funds, which should be regarded as a highly remunerative national investment for the benefit of the nation as a whole. It is accordingly our FIFTH RECOMMENDATION:

That the Government should allocate to the Department an annual sum of at least £1 million for the maintenance and expansion of its activities

Relations of Research Associations with their Members

36. The relations of research associations to subscribing members require notice. We consider it important that the director of research and his staff shall be capable of setting out the result of research in a readily assimilable form. This requires the closest association between the scientific personnel of the research association and the technical management of the individual members. It is, for example, useless to publish scientific reports in a language which the technical personnel cannot assimilate and which does not point directly to methods of applying the conclusions of the reports to the technical processes in the industry for which they are made. Some of the research associations maintain a liaison or development department specially charged with advising on how the results of the associations' investigations can best be applied to the circumstances of individual firms, an arrangement which is most valuable and which we would wish to see extended, but its success depends upon the degree of co-operation forthcoming from the firms themselves.

37. In the close association of production and research which exists with large organisations having their own research facilities is to be found much of the stimulus and inspiration on which the growth of such organisations depends. It is inherent in the organisation of the research associations that this same type of stimulus and inspiration is not experienced to the same degree, but much might be done to improve it by interchange of personnel between the research association and the industry for which it is working, and by promotion of conferences of the technical personnel of the firms concerned under the auspices of the research association.

The Scientist in Industry

38. It remains to express our views on the important question of the education of the scientific worker in industry, his standing in the firm which employs him, the conditions under which he works, and the organisation of research work from the personal point of view. As regards education, we do not consider it within our province to go into detail since it should be considered in relation to education in general rather than specifically applied to research. We desire to point out, however, that an expansion of industrial research and development postulates the necessity for providing the necessary trained personnel for conducting it, and raises the question whether the facilities for scientific and technical training are sufficiently numerous and of the necessary quality. Industry should develop the interest it has shown in recent years in recruiting trained personnel from the universities and technical colleges, and should make more general the practice of providing funds for the creation of fellowships, bursaries or the like at universities and technical schools and colleges for junior personnel already in the industry who show an aptitude for a scientific career, or to place such funds at the disposal of universities for post-graduate research in problems in which they are interested.

39. A related question is that of the proper position of the research worker within the organisation employing him, on which to some extent depends the power of industry to attract the best scientific brains to its service. In most cases the time has long since gone by when the research personnel considered themselves as being, or were kept, remote from the other branches of an undertaking and were regarded as engaged on some obscure and ancillary activity outside the main stream of the firm's interests to be called upon only when things went wrong It is nevertheless still necessary to point out that the best results can only be obtained from a firm's research personnel if they are taken fully into the confidence of the management and given a definite standing in the hierarchy of the organisation. The research worker cannot be expected to perform his duties unless he has at his disposal all relevant information which is in the possession of other branches of the organisation of which he is a member. It must be realised that the highly qualified pure scientist in general has had no opportunity of acquiring industrial experience, and consequently cannot have that background for the strategic planning of the national research effort which is so necessary at the present time, although he may be unrivalled in the tactical development of the laboratory stages of the plans adopted.

40. It is also to be remembered that publication of the scientific aspects of his work is a legitimate ambition of every scientific research worker. Experience has shewn that such ambitions are not as a rule inconsistent with the interests of firms engaged in competitive industry; on the contrary such publication increases the prestige of the firm concerned.

41. It must not be thought, however, that all that is needed for successful research and development work is the introduction of a specific number of highly qualified men. Research and development can generally only be efficient on the basis of co-ordinated team work, the team itself being properly balanced as between the leader and his various grades of assistants. The personality of the leader is of the greatest importance, and a successful leader is one who appreciates the ambitions and capabilities of the separate members of his team, and has the gift of communicating to them his own enthusiasm and a full appreciation of the objects the team is seeking to achieve, and above all for discriminating acknowledgment of the contribution made by each member of the team to the common objective.

42. The man who enters employment on the research side should not be regarded as necessarily suitable for that side only. Considerable benefit has flowed from the transfer of research workers having the requisite personal qualifications to commercial, administrative and other branches of activity. The more an organisation is staffed on all its sides by persons having an appreciation of science and research, the more progressive and adaptable to changing circumstances it is likely to be. Little benefit will be derived from increasing the numbers of those engaged on research if trained minds are not more fully employed in other branches of industry. The general scientific outlook of industry must be raised if the understanding and application of new scientific inventions, discoveries and developments by industrial concerns are to be increased. The first to exploit or apply a new discovery or invention reaps the major material advantage in increased employment and prosperity.

Taxation

43. Our Report would not be complete unless some reference was made to the influence of taxation upon research expenditure. In general we believe that a reasonable view is taken by the Inland Revenue authorities as to what items of such expenditure are chargeable against revenue, but there have been complaints in the past that costs of development have been disallowed, while such capital items as buildings have never been admissible. Recently the Federation has advanced the principle that all expenditure on research and development should be chargeable against revenue either immediately or over the commercial life of any asset created. We strongly endorse this principle in view of the great importance to the nation of the largest possible expansion of research: any

narrow interpretation of what is allowable expenditure for taxation purposes bound to have a deterrent effect.

The Desirability or Otherwise of New Machinery

44. Our first recommendation was that every firm should consider providing suitable resources for the investigation of its own problems, while our third was that each industry should create a similar fund for promoting appropriate collective research. The question at once arises whether the necessary facilities exist whereby such funds can usefully be expended, bearing in mind that only the larger firms to-day are of sufficient size to maintain fully equipped research departments, while some industries are too small to maintain independent research associations.

45. As regards collective research for an industry too small to have its own research association, the problem is relatively simple. Many existing associations cover not only a main industry but also various ancillary and related industries. We feel confident that any industry where a research association of its own is not feasible could come under the wing of some existing association willing to broaden its scope to the necessary extent.

46. The position as regards the individual firm is more difficult, and we have had under consideration various means by which its problems could be handled. In this connection we have reviewed the potential advantages for this country of an organisation similar to the Mellon Institute in the U.S.A. The Mellon Institute was founded primarily for the purpose of undertaking sponsored research problems, and, with similar Institutes, has undoubtedly performed valuable services to Industry in the United States. The personnel which they have assembled represents a wide body of experience which can be drawn upon in connection with any problem submitted, while the close contact they maintain with the firms on whose problems they are engaged, and the many successes achieved have undoubtedly stimulated a greatly enhanced interest in research, which has led in many cases to the establishment of research laboratories within the firms themselves. The Institutes have also provided important training centres for research workers, and many of their staff have ultimately taken up positions with the firms on whose problems they were working. The success of these Institutes is, however, to some extent due to the fact that there is in the U.S.A. no research association movement at all comparable with that which exists in this country. We are conscious that the future may demonstrate the need for similar facilities here in addition to those at present existing. In the meantime we feel that the firm lacking the possibility of forming its own research department should at least employ one or more persons competent to consider such matters in relation to the firm's activities, even conjointly with other functions for which they may be responsible, and would certainly be able to obtain the requisite research assistance in dealing with any specific problem from one or other of the existing research organisations.

Problems of Development

47. A further question of a somewhat similar kind is whether there exist adequate means whereby inventions or the fruits of fundamental research in universities, research organisations and similar institutions, or even by individuals can be secured to the national interest and developed up to an industrial scale. Such work is habitually undertaken by firms possessing their own laboratories but there is no machinery, equivalent for example to the Research Corporation of America, which can be utilised by organisations or individuals other than those commercially interested, to protect by patent their inventions and thus ensure their exploitation in the general interest by the control of the issue of licences at home and abroad. We consider the desirability of the creation of such machinery should be carefully investigated. Although Government funds would undoubtedly be required in connection with its establishment, it should take the form of an independent organisation, established by Charter, and not a Government organisation. The repayment of such Government funds should be a first charge on any balance of income over expenditure.

Bureau of Industrial Research

48. Experience shows the need for a continuous assertion of the over-riding necessity for industrial research so as to counterbalance the lack of appreciation which undoubtedly exists as to its potentialities, and in this connection we feel confident that some further organisation is required. Thus our SIXTH RECOMMENDATION is:

That a Bureau of Industrial Research should be established in the immediate future, which should be national in scope and, though financially supported by those principally concerned, such as research associations, independent scientific research laboratories, Governmental research establishments, universities and others should be entirely objective in its activities.

49. The Bureau would undertake the publication of a Year Book, in which could be included a short description of the achievements of British research, and of the facilities available for the prosecution of research. If information of this kind in regard to industrial research were published, there would become available for the first time knowledge of the basis and origin of the quality of British goods. In general, such a publication would bring home, not only to people in this country, but also to the world at large, the paramount influence of research on the quality of British industrial products. The Bureau might also undertake educational publicity on research; further it might advise firms whether their problems were such as to require scientific investigation, and on what scale, and accordingly how much in the way of finance and personnel would be involved. It might also prove possible for it to create a liaison between research workers in similar or related fields and thus accelerate progress.

50. In general, the existence of the Bureau would, in our opinion, serve to increase the research-mindedness of British Industry, and to create an even greater national sense of the importance of the subject and its influence in maintaining national prosperity and well-being. We are confident that such a Bureau when established would rapidly develop conditions of working which would secure general confidence and support.

Conclusion

51. We are on the whole satisfied with the general scheme of organisation by which industrial research and development is at present conducted in this country and with the various types of organisation which exist. But it is equally clear from certain of our recommendations that we are not satisfied with the scale on which research is prosecuted and the degree to which the existing machinery is utilised. It is also important that pure science should receive much greater support from Industry and the State, by the creation of research fellowships and increased grants from public funds for facilities and apparatus. It is obviously only from discoveries in the realm of pure science that new industries are likely to evolve. It is therefore essential that many of our best scientific brains should be continuously engaged on research in the sphere of pure science so that the flow of knowledge is maintained, and the foundations are being continually laid upon which further progress can be built. We hope our report will stimulate a greater provision of resources in money and personnel for all types of research than is at present available. But Industry must not only be willing to exploit the machinery for research which is at its disposal; it is even more important, both nationally and for the individual firm, that it has the will to develop the results of research to the uttermost, and to take such risks as enterprise in new fields of endeavour must involve. To be first in the field of application is of even greater advantage to a country than to have been the birthplace of the discovery. Furthermore stable economic conditions in industry are essential to a progressive research policy, which itself however is one of the principal factors in creating economic stability.

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We desire to place on record our high appreciation of the services rendered by our Secretary, Mr. John Gough, whose unremitting energy and devotion to the work of this Committee have contributed so largely to the preparation of this Report.

Summary of Recommendations and Conclusions

1. Research and technical development by industry are a natural growth from the activity of individuals in the sphere of fundamental discovery and the formulation of scientific knowledge (para. 2).

2. In the present critical period of our national economic development, the position of scientific research in connection with our industries requires urgent consideration (para. 4).

3. Industrial research and development have been of the greatest importance in the past and will have an even greater part to play in the future, from a national point of view. They are also of great importance to the individual firm (paras. 6—8).

4. While every industry and firm does not provide an equal opportunity for the application of research, no industry can maintain progress without it (para. 10).

5. The amounts spent by individual firms on research and development and by Research Associations on research represent a fraction of one per cent. of the value of industrial production; if one per cent. of the total value of our industrial production were spent on research and development, the increased productive efficiency and employment capacity would yield an annual return of many times such expenditure (para. 20).

6. Ideally, every industrial unit should maintain its own research department, since the most profitable research is that carried out by the individual firm in its own laboratories. In the present stage of industrial organisation, this is however, not possible throughout industry as a whole, and the Committee's FIRST RECOMMENDATION is that—

(a) every manufacturing firm should take stock of its position to ensure that it is devoting to research and development the maximum effort and funds, commensurate with the nature of its problems;

(b) wherever possible it should maintain its own research department; where, however, this is not feasible, it should, at least, entrust one or more suitably qualified individuals with the responsibility for keeping constantly under review the application of research to its activities, and for initiating such investigations as may from time to time prove desirable, and create and maintain a special fund for such research and development, of a magnitude compatible with its resources (para. 21).

7. Some types of problem, particularly those of general interest to an industry can best be dealt with through co-operative machinery (para 22).

8. The research associations are a well tried example of such machinery and are playing a valuable part. The research association movement should therefore, be fostered in every possible way, though the associations are not to be regarded as a substitute for or alternative to research by the individual firm, sides the associations should concern themselves with questions of interest to the industry as a whole (paras. 23—27).

9. Figures of income and expenditure in respect of the research associations show that industry in many cases fails to appreciate the benefits to be derived from association in collective research. The Committee's SECOND RECOMMENDATION is, therefore, that—

the firms comprising the industries which have their own collective research associations should give the most careful consideration now to the question whether they are making to their research association a contribution, either in money or in other ways, commensurate with the work which, if adequately supported, it could perform in furthering the interests of the industry as a whole (paras. 28-29).

10. Over industry as a whole there is room for the creation of further co-operative research machinery, and it is the Committee's THIRD RECOMMENDATION that—

every industry which has not created a collective research association should set up a co-operative research committee and take steps to create and maintain

a research fund which would equitably distribute the burden over the constituent concerns in proportion to their interest in the industry. The research committee would determine whether the scale and nature of the research needs were such as to require the establishment of a research association, whether a link could satisfactorily be formed with existing research associations, or whether research association, whether a link could satisfactorily be formed with existing research problems could be dealt with extramurally through university laboratories and other research establishments (para. 31).

11. The policy of the D.S.I.R. in respect of grants has in certain cases been somewhat restrictive, and it is the Committee's FOURTH RECOMMENDATION that—

(a) the Department of Scientific and Industrial Research should make the maximum use of the wide powers it possesses both as regards the amount of grant which can be made available in each case in relation to the countervailing contributions from the industrial subscribers to associations, and as regards the eligibility for grant of types of organisation for collective research which, though not research associations in name, are in fact fulfilling similar purposes;

(b) financial provision should be made from public funds to enable the Department to increase and continue indefinitely financial support to research associations and similar organisations as a permanent feature of the nationl economy. The main responsibility for programmes and policy should, however, continue to rest with the industries concerned (paras. 32—34).

12 D.S.I.R. should be in a position to make grants for any research or development of national importance. Such grants should be extended to cover capital expenditure, and individual companies should be eligible for contributions. The Department should also engage in greater publicity with regard to its services to industry. If the Department is to undertake these tasks it will require increased funds, and the Committee's FIFTH RECOMMENDATION is that—

the Government should allocate to the Department an annual sum of at least £1 million for the maintenance and expansion of its activities (para. 35).

13. There should be the closest association between the staff of an association and the technical management of its members (paras. 36-37).

14. If the necessary trained personnel for conducting research is to be available, industry must make more general the practice of providing funds for fellowships, bursaries and the like at universities and technical colleges and schools (para. 38).

15. If the best is to be got out of the research staff, the employing firm should take them more fully into its confidence and give them a definite standing in the hirearchy (para. 39).

16. Research and development can generally only be efficient on the basis of properly co-ordinated team work, the personality of the leader being of first importance (para. 41).

17. The research worker having the requisite personal qualifications should be regarded as available for transfer to other branches of a firm's activities. The general scientific outlook of industry must be raised (para. 42).

18. As regards taxation in relation to research, the Committee endorses the principle that all expenditure on research and development should be chargeable against revenue either immediately or over the commercial life of any asset created (para. 43).

19. An industry too small to maintain its own research association could come under the wing of an existing association. The problems of an individual firm which is too small to maintain its own research department can in the vast majority of cases be dealt with by existing means. No new machinery is at present necessary, though the future may show the need for facilities similar to those provided by the Mellon and other Institutes in the U. S. A. There is,

however, absence of adequate means whereby inventions or the fruits of fundamental research in universities, etc., or by individuals can be developed up to an industrial scale. The creation of appropriate machinery to fill this gap should be carefully considered (paras. 45—47).

20. In order to provide the means whereby the over-riding necessity of research can be continuously stressed, the Committee's SIXTH RECOMMENDATION is that—

a Bureau of Industrial Research should be established in the immediate future, which should be national in scope and, though financially supported by those principally concerned, such as research associations, independent scientific research laboratories, Governmental research establishments, universities and others, should be entirely objective in its activities.

The Bureau would undertake the publication of a Year Book and engage in educational publicity on research; it might also advise firms whether their problems required scientific investigation, and possibly create a liaison between research workers in similar or related fields (paras. 48-49).

21. Both industry and the State should give greater support to pure science, and industry must not only exploit the machinery for research which is at its disposal, but must have the will to utilise the results of research to the full and to take such risks as enterprise in new fields involves (para. 51).

VII.—SCIENCE IN INDUSTRY *

THE IMPORTANCE OF RESEARCH TO THE FUTURE

Public and Private Ways and Means: by Samuel Courtauld

No apology is needed for returning to the subject of scientific research and industry. Britain will have to make a far greater use of research in future if she is to hold a leading place in the world. Possibly, since we are more dependent upon imports of raw materials (including foodstuffs) and therefore upon exports of manufactured articles, than any other nation, industrial efficiency is more necessary to us than to all the others. What is not so clear is how great our expenditure upon research must be, and how it must be directed. In proportion to our population expenditure should be at least as great as in any other country. Many statistics lately published, though they do not all agree in detail, make it clear that the expenditure per head on industrial research in the United States and in Soviet Russia is several times as high as it is here.

As to the ways in which research may be financed and carried out, there are two possibilities, at opposite ends of the scale; wholly private and wholly public. Between these two extremities are two intermediate courses; research carried out by private industrial research departments, with regular provision for making some part of the results public and research in public institutions, mainly at public expense, but with permission to undertake as well private researches privately paid for.

Secrecy or Pooling.

It is obvious that wholly State-paid research must be directed to the benefit of the whole community, and therefore that its results must be public property. This does not necessarily mean the immediate publication of everything, though that is the ultimate logical aim. Premature disclosure while results are still in a halfbaked condition may do more harm than good. Again, it may not be wise for the nation to publish all its secrets to foreign rivals. The extent to which this holds good must obviously depend on future international arrangements.

It is also obvious that the results of any research which is wholly paid for privately are the property of the individuals concerned, who have the option of total or partial publication or no publication at all. Present-day industrial thought seems to be moving in the direction of more pooling of knowledge. It is commonly believed that there is less secrecy between industrialists in the United States than there is here, and that this more liberal attitude has aided the rapid growth of industry in that country.

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*"Times": 1 November 1943.

The extent to which this trend is followed depends upon the willingness and the financial ability of industry to take long and wide views. A private industrialist may think that it pays him to make everything public in due course, on the ground that what adds to the prosperity of the community will ultimately widen his own potential market. He cannot, with safety, take too selfish an economic view. Besides considering the desirability of the general dissemination of information which may ultimately add to his own prosperity, he is well aware to-day of other human and social forces which override economic laws and are even more dangerous to offend.

Private Profits

Still it may be true in a sense that private firms are bound to make profits their basic consideration. There are quick profits and there are long-range profits. Although the application of science may revolutionize an industry, the change may take a long time to mature, and he who counts on quick profits may quickly come to grief. Here strong financial undertakings have an advantage, for they can afford to wait. The weaker can only compete through co-operative research, each making a relatively small lock-up investment.

Short of complete publicity, industrialists may decide to pool much information with their own competitors on a reciprocal basis, thinking that co-operation will strengthen their industry, as such, to the benefit of all in it. In a similar way they may make all their knowledge about the use of their products known to all users of similar products. Or they may try to confine this knowledge to their own customers. The present writer believes that the maximum degree of publication and co-operation consistent with reasonable safeguards against abuse will accelerate the healthy growth of every industry based upon applied science. Probably the old-fashioned love of secrecy brought more harm than good to the average manufacturer.

It is impossible to say just how much it would pay the nation to spend on research, and I have no room here for comparative statistics. The cost of research practised on the most liberal scale known anywhere is a mere fraction of the value which it demonstrably creates.

Big concerns can well afford to spend much more on research than most of them have yet done, and the Government can legitimately encourage them in this by relieving the whole financial cost of it from taxation. Small businesses can contribute far more liberally to research associations, and they can make real use of these by employing men of scientific outlook, on their own staffs. The associations should be liberally and freely supported by Government contribution on a much bigger scale than hitherto. It is estimated that existing industrial research associations have a total income of £800,000 to £1,000,000 a year, which includes £200,000 from the Government. This is niggardly on both sides. It may be suggested that it is the function of the Government to support the smaller men in this way, directly; the big can better look after themselves. This will not bolster up inefficiency and undermine the strong. It will add to the industrial strength of the nation; a well-tilled and well-manured field produces the biggest and strongest plants.

It is open to question whether the Government should assist research by direct contribution, or by remitting taxation, while allowing the fruits of that research to be withheld from the nation by means of patents not fully and efficiently worked. Government-maintained institutions must, of course, have a free hand, and fundamental research will be one of their main functions. The publication of fundamental discoveries must be subjected to the decision of a very high and impartial tribunal, always with an eye on possible foreign competitors. Existing interests must not be allowed to retard publication beyond the point where these coincide with public policy; a Government research station might make discoveries which would rightly lead to the closing down of an existing industry altogether.

In all Ranks

If research is worth far more than has been recognized, the position of the scientist in industry must be raised. He must have a bigger say in the higher direction, aims, and policy; and the scientific outlook must be encouraged in

all ranks. In view of the great coming demand for men with scientific training, which will be very hard to meet, industry should notify its readiness to raise their general status without delay.

Where pure research ends and applied research begins is difficult to say, or where applied research merges into development which is itself largely experimental by nature, involving many tentative excursions and withdrawals. After the original invention has been perfected, a long time may elapse and great expenditure be required before it can be applied in a practical form to industry. Indeed, this stage may be far more costly than the original research. On such a rock many enterprises are wrecked.

Great Britain stands second to none in fundamental scientific discovery, very largely the result of work done in our universities and similar academic places. It is owing to a more intense application of such discoveries to industrial purposes that the output per man-hour in so many industries is far higher in the United States and in Germany than it is in Britain. It is not due to superior skill or energy on the part of the workers; it is more probably because British industrialists, having an ancient record of phenomenal success behind them, are ultra-conservative.

Rayon.

If I may refer to my own industry, I find that, starting from the same date with similar methods, Britain can hold her own. The viscose process, accounting for far more than half of the world's total output of rayon was started in Europe and the United States about 40 years ago. In departments covering the biggest part of the operations and producing a strictly comparable article, the output per man-hour differed very slightly in Great Britain, Germany, and the United States just before the war. The relative figures have varied from time to time; but they show that Britain can be in the van if she keeps awake and applies the results of scientific discovery wholeheartedly.

Finally, most large industries in this country are made up of a multitude of comparatively small units, and these should be given the strongest possible lead and every encouragement, including generous financial assistance, to induce them to combine in research work for the benefit of their own industries and the nation.

Nov. 1st, 1943.

VIII.—COLONIAL RESEARCH COMMITTEE

Progress Report 1942-43

Presented by the Secretary of State for the Colonies to parliament by Command of His Majesty, November 1943

Lord Hailey, G.C.S.I., G.C.M.G., G.C.I.E. [*Chairman*].

Sir Edward Appleton, K.C.B., D.Sc., LL.D., F.R.S.
Secretary of the Department of Scientific and Industrial Research.

A. M. Carr-Saunders, M.A.
Director of the London School of Economics.

Sir Hubert Henderson, M.A.
Economic Adviser to the Treasury.

Professor A. V. Hill, O.B.E., F.R.S., M.P.
Secretary of the Royal Society.

Sir Edward Mellanby, K.C.B., M.D., F.R.C.P., F.R.S.
Secretary of the Medical Research Council.

Dr. W. W. C. Topley, M.A., M.D., F.R.C.P., F.R.S.
Secretary of the Agricultural Research Council.

Early in 1943, Mr. Henry Clay was obliged to resign from the Committee owing to pressure of work which necessitated frequent absences from England. In May, the Committee heard with great regret of the death of Sir John Caelcutt, who had been a keen and helpful member since his appointment.

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APPENDICES

I.—First interim Report of the Colonial Products Research Council.

II.—Research Schemes made under the Colonial Development and Welfare Act, 1940. (*Omitted*)

III.—Colonial Agricultural Institute: Medical Research Institutes and Schools of Medicine. Veterinary Research Stations.

IV.—Centres for the collection, distribution and interchange of scientific information on agriculture and medicine, supported jointly by all countries of the British Commonwealth.

COLONIAL OFFICE,
20th September, 1943.

Colonel The Right Honourable Oliver Stanley, M.C., M.P.,
Secretary of State for the Colonies.

SIR,

I have the honour to present a progress report of the Colonial Research Committee appointed in June, 1942, to advise on the expenditure of the £500,000 a year provided by the Colonial Development and Welfare Act, 1940, for the "promotion of research and enquiry" in matters affecting the Colonies and to advise upon and co-ordinate the whole range of research in the Colonies, irrespective of the provenance of funds.

I have the honour to be,
SIR,
Your obedient servant,
HAILEY [*Chairman*].

COLONIAL RESEARCH COMMITTEE

PROGRESS REPORT, 1942-43

HISTORY OF THE COMMITTEE

1. The money voted under the Colonial Development and Welfare Act of 1940 was the first provision for colonial research made by Parliament on any comprehensive scale. At the end of the last war, Parliament voted £20,000 a year for a period of five years to further research in the Colonies, and a small Research Committee was set up to advise on its expenditure. After two initial grants of £10,000, however, the annual provision was reduced to £2,000 a year. During the ten years of the existence of the Committee, from 1919 to 1928, it undertook various small-scale research projects, but its work came to an end with the passing of the Colonial Development Act of 1929. This Act provided for the expenditure of sums up to £1,000,000 a year on "development", and research was included in this term. During the eleven years of the Act's existence, just under £600,000 were spent on research and enquiries of different kinds.

2. Considerable sums were also spent on colonial research by the Empire Marketing Board, set up in 1926 to investigate the marketing of Empire produce as a whole. The Board was originally limited to investigating the possibilities of marketing Empire products in the United Kingdom, but in 1931 this condition was removed and, during the next two years, money was spent on market and products research in the Colonies. Following the Imperial Econo-

mic Conference at Ottawa in 1932 the Board was dissolved, but in 1937 the need for further marketing research in the Colonies was felt, and a special Colonial Empire Marketing Board was appointed in 1937. This set on foot investigations into the possibilities of marketing some 50 colonial products. On the outbreak of war in 1939 the activities of this Board were suspended for the period of hostilities, or such time as might subsequently be directed by the Secretary of State.

3. In 1940 the position was changed by the passing of a new Colonial Development and Welfare Act. The Statement of Policy presented to Parliament (Cmd. 6175) announced that the Government considered it advisable that special arrangements should now be made for financing research as distinct from welfare and development, in order to establish such research on a wide and regular basis. The Act made provision for expenditure up to a maximum of £500,000 a year on colonial research, apart from the provision of sums up to £5,000,000 a year for development and welfare projects. It may be noted that no time limit was laid down in the Act for the provision made for research, in contrast to the ten-year limit assigned for the expenditure on development and welfare projects.

4. The Statement of Policy announced further that the Government proposed to establish a Committee to advise on colonial research, in order to secure for the Secretary of State the permanent assistance of a representative body of scientific experts. It may be remarked that the Colonial Research Committee constituted in 1919 had no scientific representation on it, and this was also the case with the Colonial Development Advisory Committee appointed under the 1929 Act. Owing to war conditions, however, it was not found possible to appoint the new Committee at once. Some ten grants for research were made in the interval between 1940 and 1942 without consultation with any advisory body dealing specifically with questions of research.* The present Committee was appointed in June, 1942.

FUNCTIONS OF THE COMMITTEE

5. The Colonial Research Committee of 1919, and the Colonial Empire Marketing Board appointed in 1937, dealt mainly with problems of economic development, and the majority of the grants made under the Colonial Development Act of 1929 were also directed to this purpose. In a statement made to the House of Commons on 28th April, 1942, Mr. Harold Macmillan, then Parliamentary Under-Secretary of State for the Colonies, announced that the present Committee would, on the contrary, have a two-fold purpose. In addition to advising on the expenditure of the sums provided for research by the Act of 1940, it would assist in co-ordinating the whole range of research in colonial studies, irrespective of the provenance of funds. The extent of the Committee's field of work was indicated by Viscount Cranborne, the then Secretary of State for the Colonies, in an address delivered by him at its opening meeting. He pointed out that the terms of the Act referred to "research and enquiry" and he considered that these terms should be given the widest possible interpretation. The scope of enquiry would include those problems of agriculture, human and animal health in which there was a long tradition of research in the Colonies, as well as the newer problems of applied biology, physics and chemistry. The wider but hitherto less organized field of social studies, such as economics, sociology, linguistics, and the study of colonial law and administration, seemed to him to require particular consideration in relation to colonial development. Topographical and geological surveys, engineering, and problems of industrial development would all come within the Committee's purview. He encouraged the Committee to take a long-term view of research, as well as to consider the needs of short-term enquiries. While at one end of the scale questions of pure research of the most abstract kind might need study, the Colonial Governments would also need assistance in

* *See* paragraph 60 and Appendix II.

investigations of a type that might hardly be recognized as research in the academic sense.

6. The Committee's function in co-ordinating research would, he said, be no less important than its work in recommending grants for expenditure. On the one hand, it would survey the existing facilities for research, not only in the Colonies but elsewhere. On the other, it would serve to bring the Governments of the Colonies into closer touch with such facilities. One of its most valuable contributions to colonial development would be its contact with those institutions in Europe, America and the Dominions whose work had a bearing on the problems which arise in the Colonies, or whose assistance could be invoked in their solution.

THE FIRST YEAR'S WORK

7. The Committee has held 17 meetings during the period covered by the present Report. It was aware from the first that it would not be able to carry out extended schemes of research during the war. While, as will subsequently be shown, it has been possible to maintain many of the agencies for research which already existed in the Colonies, it has not been found feasible to make any substantial expansion of their activities. But the Committee has felt that both here, and in other respects, it should not confine itself to examining proposals put to it by Colonial Governments, or by bodies interested in enquiring into problems affecting the Colonies. It conceives it as its duty to study the whole field of scientific inquiry; to distinguish the parts of it requiring attention, and to ensure that gaps in it are filled wherever it is possible to do so. It has, therefore, confined itself mainly to the preliminary task of surveying the special problems and needs of colonial research as a whole, and to an examination of the general principles which should be followed in its organisation. If future developments can now be planned on a comprehensive scale, the Government will be in a better position to put schemes of research into operation as soon as scientists, and others now engaged in war duties, are free to take part in the work of colonial development.

8. The Committee has not yet been able to complete its survey of the major subjects which must come under its review. It began with an examination of certain fields of work, such as land surveys, the magnetic and meteorological services, and research in relation to forestry, fisheries, agriculture, animal health, and some of the social sciences. It has been its first task to form some estimate of the character of the research work already undertaken in the colonial territories. While the Committee has been impressed with the efforts that have been made by research workers in the Colonies, often in the face of great difficulties, and with the value of many of the results achieved, it is convinced that scientific facilities and terms of service must be improved, and new or additional methods of recruitment and organisation devised, if research is to play an effective part in colonial development. Under existing conditions scientists and research workers in the Colonies frequently have to work in isolation, and with relatively inferior equipment. Moreover, many of them are engaged in routine investigations as well as in research, and the volume of this routine work is always liable to be increased in accordance with administrative needs. Even if they are freed from the pressure of routine examinations, there is a tendency for research problems to be dictated too exclusively by local and temporary interests, without due regard to scientific possibilities, or to the scale on which a given investigation must be planned if it is to have any reasonable hope of success. Under conditions such as these, there will always be a difficulty in attracting the most able research workers to the Colonies, and unless men and women of outstanding ability can be obtained, colonial research will never be effective. Paragraphs 24 to 30 embody certain suggestions which might go some way to solve this fundamental problem.

9. Much of the research carried out in the Colonies has so far been done under Government auspices. It is not easy to give an adequate impression of

this work, since the greater part of it has been done by officers belonging to the Government technical services, side by side with their ordinary departmental work. The technical services of the Council Governments, *e.g.*, Medicine, Education, Agriculture, Animal Health, Forestry and Labour, have developed rapidly in the last twenty years. In most Colonies these departments have specialists attached to them, some of whom perform routine work as pathologists, soil chemists or the like, while others are explicitly designated as research officers. Most Colonial Governments have clinical laboratories, agricultural plantations and experimental stations, and veterinary laboratories. But there are also a number of institutions devoted to more fundamental types of research. The more important of these, such as the Imperial College of Tropical Agricultural at Trinidad, the East African Agricultural Research Institute at Amani, the Institute of Medical Research at Kuala Lumpur in Malaya, and the Yellow Fever Research Institute at Entebbe in Uganda, have now an acknowledged position in the scientific world. Though extensions and additions to the different colonial research institutes may be required, yet in the major branches of the natural sciences, at any rate, the foundations for development have been securely laid.

10. Many Colonial Governments have shown their readiness to support programmes of research, so far as their own funds permit. It may be noted, for instance, that when the grants from the Empire Marketing Board to the sugar experimental stations in Mauritius and the sugar-cane breeding stations in Barbados came to an end, the financial burden was assumed by the Colonies themselves, and that at a time of great industrial depression. There are many other instances in which research has been both initiated and financed by Colonial Governments.

11. Unofficial and commercial undertakings have also financed a considerable amount of research in the Colonies. The Empire Cotton Growing Corporation has stations in the West Indies, West and East Africa and is planning the development of a large research institute and laboratory in Uganda. The Rubber Research Institute in Malaya and the Tea, Rubber and Cocoa Research Institutes of Ceylon have all contributed much to the prosperity of the Colonies. Sisal research has been undertaken in Tanganyika and coffee research in Kenya. Most of these investigations have been financed by a cess levied on the industry itself. The copper-mining companies in Northern Rhodesia have made an extensive geological survey, and have also made valuable investigations on native diet.

12. In more than one instance important research projects in the Colonies have been financed by different foundations and trusts as well as by academic bodies and research councils. The Sleeping Sickness Commissions organised by the Royal Society at the beginning of this century laid the foundation of our knowledge of the causation of this disease. The Liverpool School of Tropical Medicine maintained the Sir Alfred Jones Laboratory at Freetown with some contributions from local governments. Continuous research was carried out in this laboratory till 1941 when it was closed for the duration of the war. The Leverhulme Trust and the Rhodes Trust have financed individual research and the Wellcome Bureau of Scientific Research has carried out investigations on yellow fever and other subjects. The London School of Hygiene and Tropical Medicine has conducted a series of research projects in Africa and the Pacific Islands. Various Universities in the United Kingdom and the Dominions have organised and financed individual schemes. In particular, a number of recent anthropological studies have been financed from this source. The Medical Research Council has financed or assisted a number of research projects carried out in the tropics as well as giving grants for work done in this country in relation to tropical medicine. It has assisted in this way work on Yaws in Uganda, on tuberculosis in East Africa, and on nutrition in Nigeria. It recently organised a pioneer piece of research in the Nyasaland Nutrition Survey carried out under Dr. B. S. Platt with the aid of a grant under the Colonial Development Act of 1929, and a contribution from the International

African Institute. In 1936, the Council appointed a Tropical Medical Research Committee which included representatives of the Colonial Office and the Liverpool and London Schools of Tropical Medicine to consider problems of research in the tropics.

13. The Colonial Empire owes much to the generosity of American scientific foundations. The Rockefeller Foundation has financed yellow fever research in East and West Africa, hookworm surveys in the Far East and the West Indies, and other medical and public health research. It also made grants for anthropoligical and linguistic research carried out through the agency of the International African Institute. The Carnegie Corporation has given grants for locust and other types of entomological research. It has financed research in pre-history and also film investigations, and it has given liberal support to colonial libraries. It bore practically the whole cost of the preparation and issue of Lord Hailey's "African Survey", and Dr. Worthington's "Science in Africa" and Dr. Frankel's "Capital Investment in Africa".

14. Several important international research organisations have organised work that has proved of value to the Colonies. For instance the League of Nations Commission on Human Trypanosomiasis, working from 1924 to 1930, laid the foundations for the numerous studies on the subject now in progress. The International Conference of representatives of the Health Services of African territories and British India held a conference in 1932 under the auspices of the League of Nations and the Office International, while a Pan-African conference was held at Johannesburg in 1935. The Epidemic Intelligence Bureau at Singapore resulted from a conference representing the Governments and sanitary organisations of the Far East, held under the auspices of the League of Nations in 1925.

15. Apart from the work done in the Colonies themselves important investigations have been carried out in the laboratories or research institutes in the United Kingdom. From 1926 onwards the Empire Marketing Board gave grants for research on colonial products to various institutions in this country. It financed research on colonial products at the Forest Products Research Laboratory, and entomological and mycological work at the Imperial College of Science. It gave grants for nutrition work to the Rowett Institute, which led to the well-known investigations into the diet of certain tribes in Kenya by Orr and Gilks. It financed publications on storage and dietetics, and gave grants for study visits to Africa by the staff of Kew Gardens. The Imperial Institute has a Mineral Resources Department and a Plant and Animal Produce Department, and has done much valuable work on colonial products.

16. The Colonies also join with the other countries of the British Commonwealth in supporting various scientific organisations serving the Empire as a whole. Jointly with the other countries of the Empire, they support and use the Bureau of Hygiene and Tropical Medicine, a centre of information on those subjects.* The Imperial Agricultural Bureaux are clearing houses of information in twelve branches of science bearing on the problems of agriculture, nutrition and forestry. Two of them, the Imperial Institute of Entomology and the Imperial Mycological Institute, also assist in and arrange for the identification of insects and fungi, a service of which the Colonies make much use. They also participate in the Imperial Parasite Service, organised for the search for and despatch of parasites likely to be of use in the control of insects and plant pests.

17. The positive achievements of research have perhaps been most marked in the fields of medicine and agriculture, where many of the major problems have been attacked, though much remains to be done before they could be said to have been solved. Thus to take the field of medicine, work on the major tropical diseases has made considerable advances. In the case of malaria there have been numerous surveys and epidemiological enquiries, and investigations into methods of control have been carried out in Malaya,

See Appendix IV.

Ceylon and parts of tropical Africa. Many surveys of the incidence of trypanosomiasis among colonial populations have been made, and much experimental work has been done as well. Yellow fever research and investigations into typhus have been carried out in a number of areas. Epidemiological and clinical surveys into yaws have been made in Africa, the Pacific Islands and the West Indies, and enquiries into the mode of transmission of filariasis in Africa, Ceylon and Malaya and tuberculosis in East and West Africa, Malaya, Hong Kong, British Guiana and Cyprus. Many clinical and other investigations into nutritional deficiencies have been undertaken throughout the Colonial Empire. In agriculture, plant pathology and crop breeding experiments have achieved considerable results. The commercial yields of sugarcane have been improved and successful work has been done in producing a higher yield of rubber in Malaya and better cotton strains in Africa and the West Indies. The hybridization of sugarcane varieties has achieved striking success in the West Indies and Mauritius on the lines initiated in Java by Jeswiet. The life cycle of various types of locust have been studied, so that the incidence of the plague can now be predicted. In the field of animal health, immunising agents have been discovered in the case of rinderpest and pleuro-pneumonia, and it seems possible that the prevention of the major epidemics among cattle in tropical areas is in sight. A Tsetse Fly Committee of the Economic Advisory Council was appointed in 1925, and reported* in 1933. A special East African Committee reported† in 1935. Tanganyika had a special tsetse research department and considerable advances have been made in the reclamation of tsetse infected territory by the clearing of vegetation and by trapping the flies. Further large-scale measures are under contemplation. Valuable work has been done on the spread of the tsetse fly.

SPECIAL PROBLEMS OF COLONIAL RESEARCH

18. The Committee has not yet completed its survey of all the requirements of research in the Colonies. Many special characteristics of the problems of colonial research will only come to light as work proceeds. The following points, however, emerge from the discussions so far held:—

(a) The need for an extended range of research

19. It was inevitable that the investigations so far undertaken should have been directed in the main to subjects which seemed to raise practical problems of immediate importance. It has been shown in paragraph 11 how large a part commercial undertakings have played in the development of research which has been of direct interest to them. In territories where the bulk of the research has been carried out by Government technical departments, Agricultural Medical or Veterinary, it is natural that investigations should have been limited in the main to concrete problems which they have had to face. It is probable that a number of enquiries of great importance have been postponed because they do not fall within the purview of the main Colonial Departments. For instance, some Governments have had well-staffed Survey Departments, but in others sufficient staff has not been available, so that basic surveys, whether topographical or geological, do not exist in many Colonies. Again, few systematic studies of the flora and fauna of colonial areas have yet been undertaken, although these are a desirable, if not a necessary, basis for a large variety of practical investigations. It will be seen from the fisheries survey included in this Report‡ how the further development of fisheries in the Colonies depends on more detailed investigations of the species of fish living in colonial waters and their life histories.

20. On the human side, ethnographical and linguistic surveys are lacking in some areas, and there is a shortage of data on social and economic con

* The Report was published by H. M. Stationery Office as a Non-Parliamentary Publication in 1933.

† Comd. 4951.

‡ *See* paragraphs 44 and 46.

ditions. Here again, few Governments have special staff available for carrying out social investigations. Accurate vital and census statistics are also essential as a basis for many forms of social investigation, and in this field much remains to be done. Many of these surveys may well have seemed of less urgent importance than direct research into the use of colonial products, or an attack on the major tropical diseases, but it is difficult to see how far-reaching plans for social and economic development can be made without the material which such enquiries can supply.

21. The Committee, therefore, feels that an important use of the research funds now available will be the extension of the scope of investigations to be undertaken in the Colonies, especially in the case of the poorer territories which have necessarily been limited in the range of their enquiries in the past. The new financial provision should make it possible to organise basic surveys of a long-term as well as of a short-term value, and to promote research on general environmental problems as well as in the whole field of social research in which little has as yet been done in the Colonies. Besides organised research, there should be room for a growing margin of individual research on a great variety of problems. Work carried out by independent scientists of distinction and originality will act as a stimulus to local colonial officials, both administrative and technical, and to the teaching staffs and pupils of educational institutes in the Colonies.

(b) Continuity of research

22. Another difficulty encountered in the past has been the lack of continuity in colonial research. The resources of many of the Colonies have enabled them to maintain only the most basic social services. In view of the not uncommon belief that research is somewhat of a luxury or a spare-time activity of people paid for other work, it naturally tends to be one of the first items for retrenchment in periods of depression and the Committee has been impressed by the waste of colonial resources in material and human effort due to this cause. It feels that full value will not be obtained from research unless continuity is ensured. In fact it considers that one of the chief advantages of this new provision of funds under the Colonial Development and Welfare Act of 1940 is to secure such continuity. Apart from anything else, the interest of scientists in colonial problems will not be maintained without continuity of policy; nor can the training of specially-equipped workers for the solution of such problems be planned.

(c) Research affected by shortage of technical staff

23. In some of the poorer Colonies the shortage of technical staff has meant that research workers (in the absence of sufficient help from technical assistants) are obliged to give much of their time to routine work. Insufficient staffing of a department may also mean that a research officer is obliged to leave his work to help the field officers in case of sudden emergency. In many spheres of research the Committee has been given examples of this practice. It is of opinion that the money available for research will be largely wasted unless it can be ensured that the workers so employed are free to devote virtually all their time to activities that may properly be called research. The student with a real flair for research is rare, and it is a waste of his special qualities if he is kept upon routine tasks for which, in any case, he may not be particularly well qualified. The Committee feels that Colonial Governments would be well advised to consider the need for an increase in the number of technical assistants qualified to take charge of the routine operations, often wrongly described as research. The local training of assistants should be advanced as rapidly as possible to secure the same ends. Recommendations to this effect have been made in some particular fields.

(d) Isolation and restricted opportunities for Colonial research workers

24. Another fundamental difficulty from which the colonial research worker may suffer is isolation from fellow workers in his own or in kindred

field of science. It is difficult to keep in touch with new developments at a distance, and many promising research students are probably reluctant to tie themselves permanently to the Colonial Service for fear of losing contact with their colleagues and with the main streams of scientific thought. They hesitate to apply for colonial employment lest they should later be unable to return to take up work in this country should they desire to do so.

25. It is probably true to say that opportunities for promotion in the colonial research field are restricted as compared with those available in academic or industrial institutions at home. Some good research workers are probably deterred from entering the Colonial Service for fear of losing chances of promotion to senior research or academic posts in this country.

26. These difficulties should be carefully considered. It is of fundamental importance to attract research workers of distinction to the Colonies. Men and women of high quality are needed rather than the mere multiplication of research projects. There seem to be two possible ways of achieving this end.

27. In the first place, further attention needs to be given to the special conditions of service of research officers. The most important of these is greater freedom of exchange between Universities and Institutes in this country, in the Colonies, and in other countries where similar research problems are being studied. Increased study-leave would no doubt do much to mitigate the isolation of the colonial research officer, and this solution was proposed by a number of those who gave evidence to the Committee. But this provision is not in itself enough. A far more elastic arrangement for the exchange of research workers between this country and the Colonies is required. Some form of machinery by which research workers may be temporarily employed by Colonial Governments should be carefully thought out. It is worth considering the possibility of establishing separate research services under some central organisation in the United Kingdom, possibly the Colonial Office, which would provide a pool of scientific workers on which Colonies could draw. As part of this pool it might be possible to arrange for a number of younger people normally employed in independent institutions outside the Government service to be available for special purposes and emergencies and thus to act as sort of "scientific volunteer reserve".

28. In the second place, the isolation of the colonial research worker would be greatly mitigated if centres of research and learning could be developed in the Colonies themselves. The Committee has been in touch with the Higher Education Sub-Committee of the Advisory Committee on Education in the Colonies, which has been for some time studying the possibilities of developing facilities for research in such bodies as the Universities of Malta, Jerusalem, Ceylon and Hong Kong, and institutions which may prove to be the nuclei of future universities, such as Raffles College at Singapore, Makerere College in East Africa, and Achimota and Yaba Colleges in West Africa. Up to the present such centres have tended to concentrate largely on vocational training, and their research sides must be built up if they are to develop as real centres of learning in the Colonies. Both Committees felt that the increase of research facilities at these centres would fulfil two functions. It would raise the standard of learning in these nascent universities, and it would do much to remove the sense of isolation at present inseparable from colonial research

29. Both Committees also agreed that though some types of applied research require independent institutes, it is desirable, wherever conveniently possible, that research work should be carried out in, or in connection with, departments of colonial universities or colleges. Such universities should also provide facilities for independent visiting research workers if and when they are able to do so. The placing of Government research institutes in close touch with centres of higher education in the Colonies would be to the mutual advantage of both. Research workers of distinction would probably be attracted to the study of colonial problems if it could be arranged for them to be released for temporary service in the Colonies by the Universities and

research institutes of the United Kingdom and possibly of other countries as well.

30. Since holding these discussions the Committee has heard with pleasure of the appointment of a Commission to study and report on means whereby Universities and other appropriate bodies in the United Kingdom may be able to co-operate with institutes for higher education in the Colonies. It hopes that this Commission will consider the suggestions made above.

(e) The need for central and regional organisation of research

31. The Committee has considered the possible needs for central organisation of colonial research in some fields. Where research workers and equipment are short, it must be used economically, and it may well be found that central pooling of resources will best achieve this end. Where work can best be done in the laboratories or institutions of this country or of the Dominions, this should be arranged. Local institutes would then undertake the investigation of problems that could best be studied on the spot. The need for regional pooling of research facilities has already been felt, and the East African Agricultural Research Institute at Amani and the Imperial College of Tropical Agriculture at Trinidad have proved their value to groups of Colonies sharing similar environmental conditions.

32. Central and regional organisation should also prove the easiest way of securing that co-ordination between the different fields of research which is necessary if comprehensive investigations are to be made of specific problems, especially those related to development programmes. Examples of the need for such co-ordination are too numerous to detail. To take only two instances the study of human nutrition requires the co-operation of experts in medicine, dietetics, agriculture, fisheries and animal health as well as that of sociologists and economists. General social and economic surveys are required to provide basic data in relation to many other types of research, medical, agricultural and educational, as well as being necessary as a basis for framing the policies of administrative, labour, welfare, and other technical departments. Machinery for securing the co-ordination of these different types of research is particularly important at the present stage of development of the Colonies.

33. It is also important to remember that the frontiers of scientific research do not coincide with political boundaries. In so far as scientific problems in various parts of the world resemble one another, the boundaries are rather lines of latitude. It may frequently be necessary to co-ordinate work to be carried out jointly in several Colonies or in colonial territories and those of neighbouring Dominions or foreign powers. Some form of central organisation may be the simplest way of securing such co-ordination.

34. As will subsequently be seen, proposals for the central organisation of topographical and geodetic surveys have already been put before the Committee, and similar proposals may be appropriate in other fields.

(f) The question of Government control in relation to Colonial Research.

35. Unlike this country, there are in the Colonies few private funds available for the conduct of research. The bulk of funds for research must come therefore, from Government sources, United Kingdom or Colonial. The Committee has examined with interest the experience of Dominion Governments working under somewhat similar conditions.*

36. The problem naturally arises how, in these circumstances, it is possible to maintain the necessary freedom for the individual research worker. The question appears to be especially difficult in the case of social studies, which are by their nature intimately connected with the work of the administration.

37. It is at this stage only possible to indicate the general view of the Committee that the greatest elasticity must be sought in the organisation of research. Where schemes of investigation are committed to academic bodies or to research institutes, their detailed guidance must be left to such organisa-

* See paragraphs 63 and 64.

tions. As a general ideal, research should be so organised that Government investigations, and those conducted by academic or other bodies or by individuals, should exist freely side by side. In this country, research in Government establishments is frequently watched over by Advisory Councils mainly composed of independent members eminent and experienced in science, medicine, industry, etc. The advantages of this arrangement are very great, and provision should be made for similar guidance and supervision of the various aspects of colonial research.

FIELDS OF RESEARCH SO FAR SURVEYED BY THE COMMITTEE

38. The subjects which the Committee has so far reviewed are topographical and geodetic surveys, magnetic and meteorological services, agriculture (including soil science, botany, plant, pathology, etc.), forestry, fisheries, animal health, and some of the social studies. After discussion with experts in each sphere, the Committee has asked for the preparation of definite schemes for the extension or improvement of research facilities. These schemes will generally be divided into two parts—short-term and long-term. It is hoped that short-term schemes may be implemented either at once, or immediately after the end of hostilities, and that the preparation of programmes of longer range will make it possible for colonial research to take its part in post-war schemes for finding suitable employment, possibly after an appropriate period of training, for younger scientists when they are released from war service.

The conclusions reached can be summarised briefly as follows:—

(a) Topographical and Geodetic Surveys

39. The orderly planning of the land and mineral development of Colonies is impossible without accurate topographical knowledge. In many Colonies this knowledge is incomplete. In some instances primary geodetic surveys have not been done and consequently the preparation of accurate topographical maps is impossible. The Committee accepted the proposal put before it by the Colonial Survey and Geophysics Committee to the effect that a central colonial survey organisation would best plan the work required. Such an organisation would undertake geodetic and topographical surveys, publish the work done, hold the required equipment and keep the necessary records. The Committee recommended that a detailed scheme for such an organisation be prepared so that the necessary plans could be immediately put into operation at the end of the war, when men at present engaged on military or other duties of national importance should be available. Such a scheme is now being prepared by the Colonial Survey and Geophysics Committee and will be referred to the Committee later.

(b) Magnetic and Meteorological Services.

40. Continuous magnetic observations requiring a network of magnetic stations spread over wide areas, including colonial territories, are needed as a basis for charts for air and sea navigation, as a means of assisting mining developments, and in the preparation of topographical maps. At present the Colonies are not taking their full part in what is essentially an international scientific duty.

41. Meteorological observatories are also required since the recent rapid development of flying has added greatly to the importance of weather knowledge and forecasts. Meteorological observations are of value to agricultural departments and if supplemented by other geophysical measurements (*e.g.*, of ionospheric phenomena) may be of considerable importance in the development of wireless transmission and radio navigation aids. A number of further observatories is required in the Colonies.

42. The Committee recommended that detailed proposals for an extension of colonial magnetic and meteorological services should be prepared without undue delay. A scheme of this kind is also under active consideration by the Colonial Survey and Geophysics Committee.

(c) Forestry

43. The Committee considered the facilities for forestry research under three headings—silviculture, economic research, and entomology and mycology. It

was agreed that central organisation of colonial forestry research was already adequately carried out by existing organisations, *i.e.*, the Imperial Forestry Institute at Oxford, the Forest Products Research Laboratory at Princes Risborough and the Colonial Forest Resources Development Department. In the Colonies, however, regional centres for research into forest products will be necessary. In the case of West Africa, East Africa and the West Indies the establishment of forestry research units for groups of Colonies should be considered. The staff concerned with entomological research and silviculture ought to be considerably increased in the case of most Colonies.

(d) Fisheries

44. The economic importance of colonial fisheries is considerable and the nutritional value of an increased fish supply for the populations of the Colonies can hardly be exaggerated. Research is required into the systematic classification of colonial fishes with the study of their life histories. Investigations into fishing methods is also necessary since many colonial waters are fished by men using primitive craft and nets which prevent them making full use of their fish supplies. Methods of preserving and processing fish need investigation, as well as the marketing and transport of supplies.

45. For this purpose further marine fisheries research stations are required, especially in the West Indies, West Africa and East Africa, while the work of the existing fisheries departments of Ceylon, Malaya and Hong Kong should be extended. The establishment of a regional research station for freshwater fisheries in East Africa would also be valuable and here, and elsewhere in the Colonial Empire, investigation of the possibility of introducing fish ponds could well be undertaken.

46. The Committee recommended that a Colonial Fisheries Service comparable to the Colonial Agricultural, Forestry and Veterinary services should be established, and that a Fisheries Adviser be appointed together with an advisory committee attached to the Colonial Office *

(e) Agriculture

47. The Committee received a survey of the present position of agricultural research in the Colonies approved by the Advisory Council of Agriculture, Animal Health and Forestry. It reviewed the progress in the organisation of agricultural research since the recommendations of the Imperial Agricultural Research Conference in 1927† and the two Lovatt Committees on Agricultural Research and Administration in the Colonies in 1927 and 1928‡. These advances consisted of: (*a*) the appointment of an Advisory Council on Agriculture in 1929; (*b*) an increase in specialist (research or scientific) staff attached to the colonial departments of agriculture in all the larger dependencies to carry out short-range *ad hoc* investigations; (*c*) the setting up of two of the chain of central research stations recommended by the Lovatt Committees for the organisation of long-range research programmes and the investigation of special problems common to several territories, *viz.*, the Imperial College of Tropical Agriculture in Trinidad and the East African Research Station at Amani in Tanganyika; and (*d*) the establishment of a number of crop research stations of varying size in certain dependencies. A list of research stations in individual Colonies is given in Appendix III.

48. Agricultural research in the Colonies has been much disorganised by war demands since many research workers have been employed on agricultural production drives, food control, general administration and other duties. The whole staff of the East African Agricultural Research Station has been largely employed on the solution of *ad hoc* technical problems arising out of military and civil requirements. Certain lines of work have been maintained and a

* Since the passing of this recommendation, a Fisheries Adviser and a Fisheries Advisory Committee have been appointed. The advisability of forming the officers of the various Fisheries Departments into a unified Colonial Fisheries Service will no doubt also be considered.

† Published by H. M. Stationery Office as a Non-Parliamentary Publication in 1928.

‡ Cmd. 2825 and Cmd. 3049, respectively.

few investigations instituted on problems of urgent importance. The Committee considers that it is essential that research work on a full scale should be resumed at colonial centres as soon as possible with such measure of reorganisation and extension as may be necessary to meet requirements of post-war development.

49. There is scope for the further provision of staff and facilities for research on the cytological side of plant genetics, on plant physiology with special reference to plant disease, on virus diseases of plants, and on trace elements; on the mapping and classification of soils, on erodibility of soils, on soil moisture relationships and on tillage problems; on the control of insect pests both by biological means and the use of insecticides and on insect pests affecting stored products; on the improvement of food and fodder crops and their feeding and nutritional value; on the improvement of pastures. There is also need for increased investigation of the economics of crop production, the marketing and transport of agricultural products, as well as on irrigation and drainage, agricultural engineering and the construction of farm buildings suited to colonial conditions.

50. Besides these special types of work, the Advisory Council of Agriculture, Animal Health and Forestry have emphasised that agricultural research needs to be placed in line with modern views of agricultural policy such as those reflected in the recent pronouncements made at the United Nations Conference on Food and Agriculture at Hot Springs. A policy of concentration on raising the standard of living of colonial peoples and particularly their nutritional standards can only be implemented by means of co-ordinated schemes of land utilisation surveys, forestry research, experiments in methods of improved cultivation in backward areas by the introduction of better strains of crops and mixed farming systems suitable to local conditions, improved storage, grading and marketing and a co-ordinated policy for the improvement of human and animal nutrition.

51. To secure planned development of this sort, the closest interdepartmental co-ordination will be necessary. It is understood that this question, as well as the general problem of the organisation of agricultural research in the Colonies, and its relation to medical and sociological research, is under careful consideration by the Colonial Advisory Council of Agriculture, Animal Health and Forestry. The Committee hopes to make definite recommendations at a later date.

(f) Animal Health

52. The Committee considered a survey of the position regarding veterinary research in the Colonies. It was agreed that for the development of research in animal health regional research centres are required for each group of territories with, if necessary, separate laboratories for the production of biological preparations. Each Colony should also have a small laboratory for the study of its own local problems and its own pathological work. The beginnings of a regional research station for East Africa exist at Kabete in Kenya and this institution would have been developed if it had not been for the war. In West Africa, the Nigerian Research Laboratory at Vom could well be expanded to form a West African research station. In the West Indies a preliminary disease survey of the Caribbean is required in co-operation with the veterinary services in Venezuela, British Guiana and the bordering provinces of Brazil.

53. The Committee recognises that in the initial stages of veterinary research in the Colonies effort must be directed towards the control or elimination of the most destructive stock diseases, and to this end continuous preventive inoculation of susceptible animals will be required, together with research on methods of immunization against some diseases, and reliable diagnostic re-agents for others. But this first stage of research upon problems of disease should be followed by research directed towards the general question of live-stock improvement in relation to the maintenance of healthy and productive herds to supply the nutritional and economic requirements of colonial peoples. To this end research on animal health will, in the future, require organisation on a wider

basis. Investigation must be undertaken into such subjects as the connection between wild game and disease, nutritional deficiencies, pasture improvements, supplementary foodstuffs, genetics and the influences of climate on live stock. Such inquiries will require the co-operation of teams of workers in different scientific fields. The problem of securing collaboration between soil scientists, pasture research workers, geneticists, botanists, general agriculturists, nutritional experts and pathologists is as important in the sphere of animal health as it is in the case of agriculture.

54. The Committee hopes to receive definite recommendations for the organisation of research in animal health along these lines from the Advisory Council on Agriculture, Animal Health and Forestry.

(g) Medicine

55. This important field of research has not yet been considered by the Committee in any detail. It is understood that plans for the better organisation of medical research are under active consideration by the Colonial Advisory Medical Committee and will shortly be presented to the Committee.

(h) The Social Sciences

56. Knowledge of the social and economic conditions and of the cultural characteristics of colonial peoples is necessary in the framing of all schemes of development, whether medical, agricultural, veterinary or educational, and for the planning of the general economic policy of a territory. Such data are very inadequate in the case of most colonial territories. The reasons are not hard to find. In this country the results of scientific investigations of social problems are only now being applied to the conduct of domestic policy. In the Colonies there have been special difficulties in carrying out such investigations. While all departments have naturally been concerned with social questions, none has been specially responsible for the conduct of detailed investigations in these fields, nor have departments of social studies yet been attached to colonial institutes of higher education. The recent provision of funds under the Act of 1940 for the setting up of a West African Institute to be attached to Achimota College will be a first experiment in the establishment of a regional centre of social and linguistic studies.

57. The Committee has encountered its own difficulties in dealing with this subject. The social sciences cover a wide field and they are on the whole less well organised than the natural sciences. There is at present no organisation acting for the social sciences, as, for instance, the Royal Society acts for the natural sciences. Again, there is no organisation financed by the Government to assist research in the social sciences parallel to the Department of Scientific and Industrial Research, the Medical Research Council and the Agricultural Research Council. It has, therefore, been thought advisable to seek the advice of a number of groups of experts in particular spheres. They cover the following subjects: linguistics; demography, anthropology and social surveys; economics; systems of colonial law; colonial administration; education and psychology. On the basis of the reports of these groups the organisation of research in the social sciences will be further considered by the Committee.

PARTICULAR RESEARCH SCHEMES SO FAR APPROVED UNDER THE COLONIAL DEVELOPMENT AND WELFARE ACT

58. Research schemes may be submitted to the Committee in a number of different ways, and it is intended that there should be the greatest possible elasticity in the arrangements made for this purpose. Probably the bulk of the schemes will be submitted by Colonial Governments themselves, but the Secretary of State will also place before the Committee projects which have been recommended to him by his various Advisory Committees (Medical, Education, Agricultural, Animal Health, Labour, Social Welfare, Economic Advisory, etc.) or schemes prepared in the Colonial Office itself. Similarly, though the Committee is not itself an executive body, it was always contemplated that it might wish to initiate research schemes by inviting research organisations to undertake them, or by recommending the appointment of

special persons to take charge of the work. Applications made by research institutes or Universities in this country or in the Colonies will be referred to the Committee by the Secretary of State.

59. Finally, the Committee hopes also to be able to consider applications for grants from individual research workers? It believes it to be an important part of its duties to encourage research in the Colonies in the pure as well as the applied sciences, and to give young scientists an opportunity of acquiring first-hand knowledge of the environmental and social problems of the colonial territories by carrying our research projects along the lines of their own interests in these territories. It has, therefore, recommended the establishment of Colonial Research Fellowships so as to build up a cadre of young men and women familiar with colonial scientific problems and able to help in their solution. It also believes that it may be of value to finance occasioned pieces of research by senior scientists holding academic or other research posts.

60. Owing to war conditions, few schemes of research have actually been approved under the Colonial Development and Welfare Act. The details are given in Appendix II.* Six of these schemes merely provide for the continuation of work already financed under the terms of the Colonial Development Act of 1929. Five of the grants have been made to research institutes or individuals working in this country, and the other sixteen institutes in the Colonies. Nine of the projects deal with problems that may roughly be described as agricultural (vegetable insecticides, the mineral content of natural pastures, sisal research, the diseases of cocoa, low-temperature research on methods of storing fruit from the West Indies, research on swamp soils for rice production, the breeding of experimental types of sugar cane in Barbados); one scheme deals with forestry research (preservative treatment for ply-wood); four are fisheries investigations (including surveys of the Caribbean waters off Barbados, Jamaica and Trinidad); one deals with animal health (rinderpest control); two with medical research (sleeping sickness and the bionomics of *anopheles gambiae*); one with a demographic survey of the Colonial Empire; one with a linguistic study in the Gold Coast; and one with a geological survey (British Guiana).

61. The most important item of expenditure hitherto undertaken under the new Act is the grant made for an organisation to conduct research into the utilisation of colonial products. This organisation, the Colonial Products Research Council, is under the chairmanship of Lord Hankey, and is independent of, though closely associated with, the Colonial Research Committee. The decision to create it was actually taken by the Secretary of State in 1941 before the Research Committee itself was appointed. Unlike the latter, the Council is an executive body; it organises research, and has its own Director of Research (Dr. J. L. Simonsen). By the courtesy of Lord Hankey the first interim report of the Colonial Products Research Council is reproduced as Appendix I to the present Report.

62. Apart from schemes actually approved under the Act the Committee has recommended to the Secretary of State some other proposals now under consideration by Colonial Governments. These include: (*a*) the investigation of alternative methods of producing cinchona. The present war has shown the dangers of concentrating in one territory the production of a substance so essential as quinine, and the scheme contemplates the establishment of a new Cinchona Research Institute in East Africa to experiment in methods of local production. The Research Committee has recommended that the scheme be put into operation as soon as possible after consultation with the East African Governments; (*b*) rinderpest and tsetse fly research. The Committee is being furnished with a special report from the East African Government on these two subjects.

INTERNATIONAL AND IMPERIAL ASPECTS OF COLONIAL RESEARCH.

63. The Committee feels that it should take every opportunity of establishing contact with interested individuals and organisations in other countries, and perhaps particularly with those within the British Commonwealth

*Omitted here to save space.

Scientific work in South Africa may be of vital interest to British Colonies in Africa, and many Australian scientists are specially engaged in research on problems common to all tropical territories. The Committee, therefore, took the opportunity of inviting Professor (Brigadier) Basil Schonland, F.R.S., the Director of the Bernard Price Geophysics Institute at Johannesburg, to discuss with it matters of common interest in connection with research in Africa. Dean C. J. Mackenzie, the Acting President of the Canadian National Research Council, was able to attend a meeting of the Committee during a recent visit to England and described to it the work of his Council. The scientific liaison officers of Australia and New Zealand, Mr. F. G. Nicholls and Mr. A. L. Poole, respectively, also described the work of the National Research Councils of their countries. Following these meetings, permanent contact has been established with those scientific liaison officers of the Dominions who have been appointed in London.

64. The Committee has read with interest and approval the report of the British Commonwealth Science Committee set up by the Royal Society on the means by which contact between scientists and the English-speaking world can be maintained. It hopes that effect will be given to its recommendations. Close contact already exists between the scientists of this country and those of the United States, and these contacts have become closer during the course of the war. The Committee considers that collaboration with the scientists of foreign powers is equally important for many parts of the Colonial Empire as are the links between the different Colonies themselves. There are many scientific problems common to the British Colonies in Africa and to those of Belgium, France and Portugal. In the Pacific, collaboration with Dutch scientists should be part of any scheme as well as joint work with those of Australia and the United States. The Committee, therefore, hopes to maintain contact scientists of these countries and those of the Colonies.

ANNUAL REPORT.

65. The Committee proposes in the future to present an annual report in April, *i.e.*, of the end of the financial year.

APPENDIX I.

COLONIAL PRODUCTS RESEARCH COUNCIL.

FIRST INTERIM REPORT.

The Colonial Products Research Council was constituted by the Secretary of State for the Colonies in January, 1943, under the Chairmanship of the Rt. Hon. Lord Hankey, G.C.B., G.C.M.G., G.C.V.O.

The Council has held four full meetings, apart from meetings of the Scientific Panel, on which devolves the function of preparing specific schemes of research for the approval of the Council.

2. The membership of the Council is as follows :—

Mr. Eric Barnard, D.S.O. (Department of Scientific and Industrial Research) :
Mr. G. L. M. Clauson, C.M.G., O.B.E. (Colonial Office) :
Mr. Aneurin Davis (Co-operative Wholesale Society) :
Dr. J. J. Fox, C.B., O.B.E., D.Sc., F.R.S (Government Chemist) :
Professor W. N. Haworth, D.Sc., F.R.S. (University of Birmingham) :
Sir Harry Lindsay, K.C.I.E., C.B.E. (Director, Imperial Institute) :
Sir Edward Mellanby, K.C.B., M.D., F.R.C.P., F.R.S. (Medical Research Council) :
Professor Sir Robert Robinson, D.Sc., LL.D., F.R.S. (Dyson Perrins Laboratory, Oxford) :
Mr. G. W. Thompson (Representative of Scientific Workers on the Trades Union Council) :
Dr. W. W. C. Topley, M.A., M.D., F.R.C.P., F.R.S. (Agricultural Research Council) :
Professor J. L. Simonsen, D.Sc., F.R.S. (Director of Research, Colonial Products Research Council).

3. The terms of reference of the Council are :—

"To review the field of Colonial production, and to advise what Colonial raw materials are likely to be of value to the manufacture of intermediate and other products required by industry; in consultation with the Director to initiate and supervise researches, both pure and applied, on such products, and generally to consider how by the application of research greater use can be made of them.

"In framing their programme the Council will have as their objective the promotion of the welfare and prosperity of Colonial peoples, and will endeavour also to increase the Colonial

contribution to the welfare and prosperity of the British Empire and of the world as a whole.

"The Council will ensure that full use is made of existing research organisations, in particular the Department of Scientific and Industrial Research, the Medical Research Council and the Agricultural Research Council. In formulating its research policy, it will also call into consultation persons with expert knowledge in science, industry and other related fields."

4. Under the terms of reference, no colonial product of any kind is outside the scope of the Council but at an early meeting the Council decided, as a matter of practical convenience, initially to concentrate its attention on those commodities, or groups of commodities which, while of great economic importance to the Colonies, are least well served by existing public or private research or development organisations. The Council accordingly decided to leave over for the present research on rubber, textile materials, timber, tea, and metals such as tin and copper.

5. The procedure adopted by the Council, for the present at any rate, modelled on and adapted from that of the Department of Scientific and Industrial Research, the Medical Research Council and the Agricultural Research Council, is to make the fullest possible use of existing research facilities in Universities and other institutions, delegating to them, the investigation of specific problems on terms mutually arranged. This procedure has many advantages, as compared with the concentration of all research work in a single institution devoted wholly to research on colonial products. It enables work to be put in hand without waiting for the establishment of a central institution, which could not speedily be done in time of war. It enables specific problems to be referred to the institutions best fitted to undertake them, and where they fit in with the work and qualifications of the existing research staff. It also spreads knowledge of and interest in colonial scientific problems, prevents colonial researches from being isolated from the broad stream of research in general, and increases the likelihood of discoveries in other researches being made available for the benefit of the Colonies. In addition, close contact is maintained with industry, which is in some fields engaged in closely related spheres of research. Actually some of the work of the Council has been undertaken at the request or suggestion of industry.

6. The Director of Research, moreover, maintains contact with research institutions abroad notably in the Dominions and India, with the object of securing a mutually profitable interchange of information and allocation of effort.

7. In framing its immediate programme, the Council has decided to initiate researches on certain commodities, on the production of which very large numbers of colonial peoples depend for their livelihood. These include sugar, vegetable oils, and certain essential oils, notably clove oil, the market for which is of vital importance to the welfare of the people of Zanzibar, and citrus oils. At the request of the Medical Research Council, the Council is also engaged in reviewing the field of research into vegetable drugs. A statement of researches planned or actually initiated is given in tabular form, together with details of the institutions where the work is being carried out, and the names of the scientists in charge :—

(1) *Sucrose and Sucrose Derivatives*—University of Birmingham, Professor W. N. Haworth.
(2) *Eugenol and Isoeugenol*—University of Durham, Professor R. G. Clemo.
(3) *Lime Oil, Lime Juice and Citrus*—Imperial College of Science and Technology, Professor L. M. Heilbron.
(4) *Fixed Oils and Fats*—(1) University of Liverpool, Professor T. P. Hilditch; (2) Lister Institute, Dr. Ida Smedley-MacLean.
(5) *Caffeine and Theobromine*—University of Manchester, Professor A. R. Todd.
(6) *Petroleum Products*—Dyson Perrins Laboratory, Oxford, Professor Sir R. Robinson. in consultation with the Research Department of Trinidad Leaseholds Limited.
(7) *Production of Ergosterol*—Department of Scientific and Industrial Research, Chemical Research Laboratory, Dr. A. C. Thaysen.

8. This list is not exhaustive, since the Council is also co-operating with other Departments in work, details of which must for the present be kept secret.

9. The Director of Research has been accommodated at the Imperial Institute, by the courtesy of the Director, Sir Harry Lindsay, and the consequent ready availability of the Institute's store of information on colonial products is of the greatest value.

10. The functions of the Council and the Imperial Institute do not in any way overlap. It will be the function of the Council to organise and to sponsor fundamental and applied researches on colonial commodities, with the primary object of finding new uses for them; whereas the Institute will continue its most important work of the chemical investigation of Empire raw materials in accordance with its statutory obligations and of furnishing information, to both producers and potential consumers on sources of supply, markets, the techniques of preparing commodities for commercial and industrial use, and the economic possibilities for any given commodity on the basis of existing industrial uses, etc. It is hoped that the Council and the Institute by general co-operation and mutual transfer of problems for investigation, will be able to supplement and second one another's work to the great benefit of colonial economics.

HANKEY, *Chairman*,
Colonial Products Research Council.

2nd September, 1943.

APPENDIX III.

COLONIAL AGRICULTURAL INSTITUTES (Research by Agricultural Departments excluded).

West Indies.	*Africa.*	*Mediterranean and Middle East.*	*Ceylon.*	*Mauritius.*	*Malaya.*
Trinidad.—Imperial College of Tropical Agriculture (chemistry, soil science, plantbreeding, low temperature research, training of agricultural officers). Financed by Imperial funds, Colonial Governments, private sources and endowments. Staff=26. Cacao research (financed by Nigeria, Gold Coast, Trinidad and Grenada). *Barbados.*—West Indian Central Sugar Cane Breeding Station (genetics and plant breeding). Financed by Barbados, Jamaica, Trinidad, Leewards. Staff=4. *Trinidad and St. Vincent.*—Empire Cotton Growing Corporation Station (genetics and plant physiology). Financed by levy on industry.	WEST. *Gold Coast.*—Cacao research station at Tafo for all West Africa (all branches). Financed by Government. Staff=5. *Nigeria.*—Oil palm research station at Benin for all West Africa. To be financed by Colonial Development and Welfare funds. Staff=3. EAST. *Tanganyika.*—East African Research Station at Amani (botany, ecology, biochemistry, entomology, plant pathology, plant breeding). Financed by East African Governments and Colonial Development and Welfare funds. Staff=13. Coffee research station at Lyamungu. (Government and Colonial Development and Welfare grant.) Staff=4. Sisal experimental station at Mlingauo. Financed by cess and Colonial Development grant. Staff=2. *Kenya.*—Coffee experimental team at Nairobi. Financed by cess. Staff=5. *Nyasaland.*—Tung oil cultivation station. *Projected.*—Empire Cotton Growing Corporation Station at Kampala.	*Palestine.*—Agricultural Research Station at Rehoboth (all branches). Financed by Jewish Associations.	*Tea Research Institute.* Financed by cess. Staff=16. *Rubber Research Institute.* Financed by cess. Staff=8. *Cocoa-nut Research Institute.* Financed by cess. Staff=5.	*Sugar Experimental Station.* Financed by cess. Staff=7.	*Rubber Research Institute.* Financed by cess. Staff=25.

Medical Research Institutes and Schools of Medicine.

West Indies	*Africa*	*Mediterranean and Middle East*	*Ceylon*	*Mauritius*	*Malaya*	*Hong Kong*	*Pacific*
	West						
Government Medical Research Laboratories in *British Guiana Trinidad* and *Jamaica*.	*Nigeria*.—Research laboratory and School of Medicine at Yaba. Financed by Colonial Government. *Gold Coast*.—Medical laboratory at Accra. *Sierra Leone*.—Sir Alfred Jones Laboratory at Freetown. Under the aegis of the Liverpool School of Tropical Medicine. At present in abeyance. East *Kenya*.—Medical Research Laboratory at Nairobi. Financed by Colonial Government. *Uganda*.—Mulago Medical School, Makerere College. Financed by Colonial Governments, fees and endowment. Medical laboratory at Kampala. Financed by Colonial Government. Yellow fever Research Institute at *Entebbe*. Financed by Rockefeller Foundation with small Colonial grant. *Tanganyika*.—Medical laboratory at *Dar es Salaam*. Financed by Colonial Government. Biochemical laboratory at *Dar-es-Salaam*. Financed by Colonial Government.	*Malta*.—University Medical School. Financed by Colonial Government. *Palestine*.—Government Medial Research Laboratories. Medical Research Laboratory attached to Hebrew University.	*Medical College*. Financed by Colonial Government. *Department of Nutrition Research*. Financed by Colonial funds.	Government Medical Research laboratory.	King Edward VII College of Medicine at Singapore Financed by Colonial Government and fees. Institute of Medical Research at *Kuala Lumpur*. Financed by Colonial Government.	*University and College of Medicine*. Financed by Rockefeller grant, endowment and Colonial Government.	Medical School at *Suva Fiji*. Financed by Colonial Government.

Central Medical Institutes

London School of Hygiene and Tropical Medicine.
Edinburgh School of Tropical Medicine.
British Empire Leprosy Research Association.
Liverpool School of Tropical Medicine.
Welcome Bureau of Scientific Research (Yellow Fever).

VETERINARY RESEARCH STATIONS *

Africa	*Mediterranean.*
WEST	
Nigeria.—Veterinary laboratory at Vom. Financed by Colonial Government.	*Palestine.*—Well-equipped laboratories at Jerusalem (All branches.)
Gold Coast.—Small veterinary laboratory for manufacture of vaccines at pong Tamale. Financed by Colonial Government.	
EAST	
Kenya.—Veterinary research station at *Naivasha.* (Nutriton, Genetics.) Financed by Colonial Governments.	
East Africa Research Institute at *Kabete* (animal pathology). Financed by East African Governments.	
Kenya research laboratory at *Kabete* (all subjects). Financed by Kenya Government.	
Northern Rhodesia.—Laboratory at Mazabuka. Financed by Colonial Governments.	
Nyasaland.—Small diagnosis laboratory at Blantyre. Financed by Colonial Government.	
Tanganyika.—Shinyanga Research Laboratory of the Tsetes Department.	

*No Veterinary Research Stations have, as yet, been established in other parts of the Colonial Empire.

APPENDIX IV

Centres for the collection, distribution and interchange of scientific information on agriculture and medicine, *supported jointly by all countries of the British Commonwealth.*

A.—*Imperial.*—Under the administrative control of an Executive Council representing all parts of the British Commonwealth.

Addresses :—

The Executive Council,
2, Queen Anne's Gate Buildings,
Dartmouth Street, London, S.W.1.

Imperial Institute of Entomology—
British Museum (Natural History), Cromwell Road, London, S.W.7.
Publications Office, 41, Queen's Gate, London, S.W.7.
Temporary Address—Imperial Institute of Entomology, Parasite Service, Belleville Laboratory, Belleville, Ontario, Canada.

Imperial Mycological Institute—Ferry Lane, Kew, Surrey.

NOTE.—These two Institutes also assist in the identification of insects and fungi. The Parasite Service searches for and ships parasites likely to control insect pests and weeds.

The Bureau of Animal Nutrition covers also scientific information on human nutrition.

The Imperial Agricultural Bureaux

Imperial Bureau of :—
Soil Science—Rothamsted Experimental Station, Harpenden, Herts, England.
Animal Health—Veterinary Laboratory, New Haw, Weybridge, Surrey, England.
Animal Nutrition—Rowett Research Institute, Bucksburn, Aberdeen, Scotland.
Plant Breeding and Genetics—School of Agriculture, Cambridge, England.
Pastures and Forage Crops—Welsh Plant Breeding Station, Penglais, Aberystwyth, Wales.
Horticulture and Plantation Crops—East Malling Research Station, East Malling, Kent, England.
Animal Breeding and Genetics—Institute of Animal Genetics, University of Edinburgh, King's Buildings, West Mains Road, Edinburgh, Scotland.
Agricultural Parasitology (Helminthology)—Institute of Agricultural Parasitology, Winches Farm Drive, Hatfield Road, St. Albans, Herts, England.
Forestry—Imperial Forestry Institute, 39, Museum Road, Oxford.
Dairy Science—National Institute for Research in Dairying, Shinfield, Reading.

B.—Under the Administration of the Secretary of State for the Colonies.
The Bureau of Hygiene and Tropical Diseases—London School of Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

C.—Under the Administration of the Department of Overseas Trade.
(For information in minerals.)
The Imperial Institute—South Kensington, London, S.W.7.

GIPD—L2001&CS—8-8-44—1000.

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on 01 February, 2020